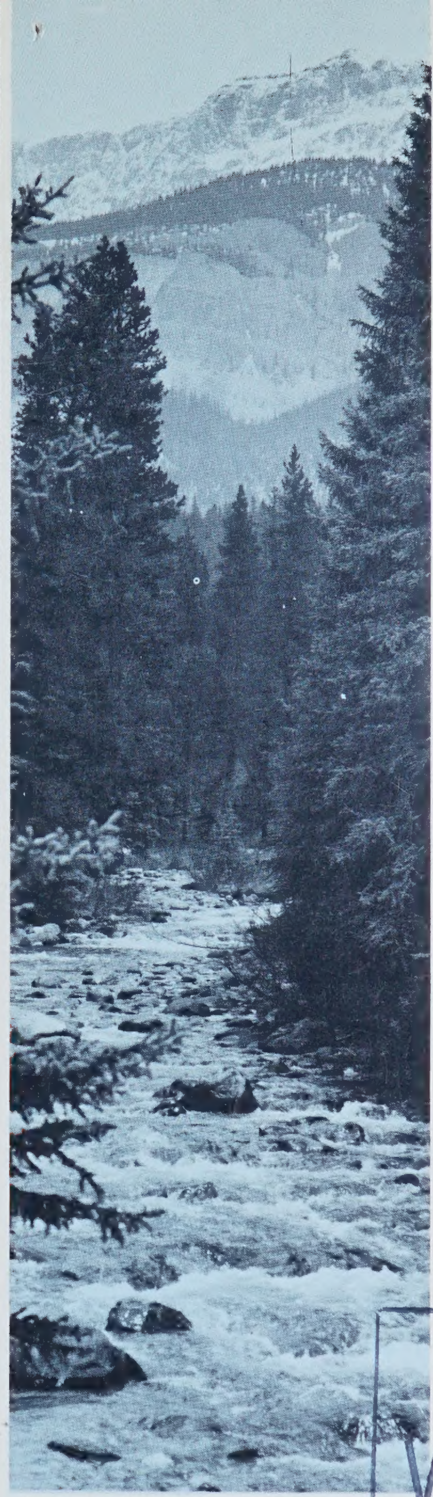
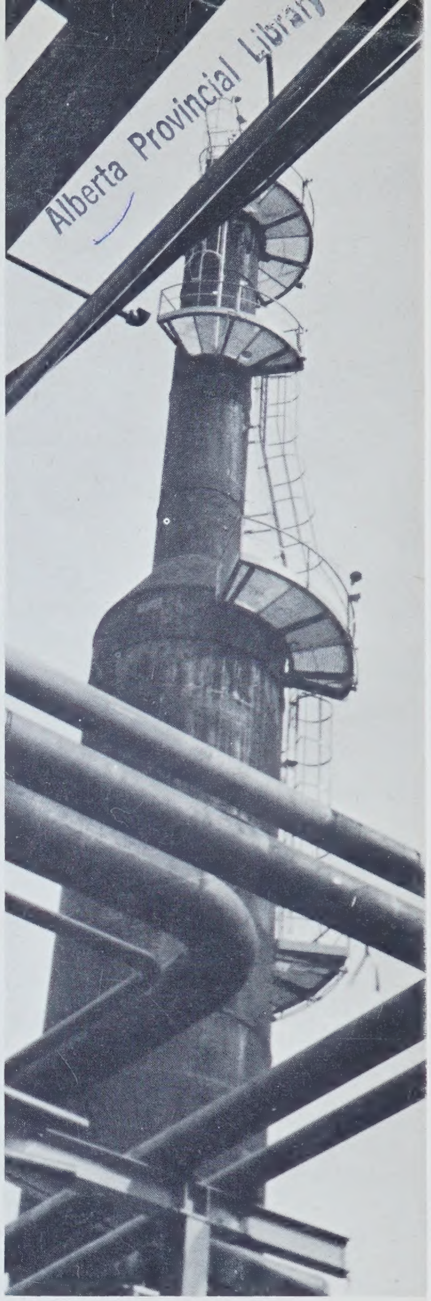
CA2ALEN 60
72R26
C.1

CA2 ALEN 60 1972R26
Alberta Resources Railway; Smoky River Study. Dec. 1972. 1
3 3398 00133 4217





alberta
department
of the
environment

Technical Services Division

HON. W. J. YURKO, MINISTER

DR. E. E. BALLANTYNE, DEPUTY MINISTER

LIBRARY
VAULT 19

# ALBERTA RESOURCES RAILWAY

# SMOKY RIVER STUDY

Digitized by the Internet Archive
in 2024 with funding from
Legislative Assembly of Alberta - Alberta Legislature Library

Alberta Department of the Environment

Technical Services Division

Submitted by: R. K. Deeprose, P. Eng.
Director
Technical Services Division

Prepared by: E. K. Yaremko, P. Eng.
Acting Branch Head
River Engineering

D. Barton, P. Eng.
Project Engineer
Planning Division

# ALBERTA RESOURCES RAILWAY

# SMOKY RIVER STUDY

December, 1972

Edmonton, Alberta

Digitized by the Internet Archive
in 2024 with funding from
Legislative Assembly of Alberta - Alberta Legislature Library

https://archive.org/details/ableg_33398001334217

# TABLE OF CONTENTS

Alberta Resources Railway - Smoky River Study (Summary)

Appendix A - Damaged Sections of Alberta Resources Railway

Appendix B - Hydrology

Appendix C - Hydraulic Analysis

Appendix D - Repair of the Alberta Resources Railway

Appendix E - Flood Control Dam

Appendix F - Photographic Coverage of Alberta Resources Railway along Smoky River

# ALBERTA RESOURCES RAILWAY - SMOKY RIVER STUDY

I. The following discussion is a summary of the technical appendices contained in this report. Each appendix deals with the following subject:

Appendix A - Observations on the present condition of the Alberta Resources Railway from Mile 104 to Mile 169.

Appendix B - Hydrological analysis of the 1972 Smoky River flood.

Appendix C - Channel hydraulic analysis of the surveyed cross-sections.

Appendix D - Estimated costs of repairing and properly protecting A.R.R. embankment from Mile 104 to Mile 169.

Appendix E - Study of a flood-control dam on the Smoky River near Grande Cache.

Appendix F - Photographic coverage of the A.R.R. along the Smoky River.

II. Approximately 7.6 miles of A.R.R. track and embankment has been completely destroyed with only a small accumulation of rubble and fill to indicate the one-time existence of a railway grade. A further 7.8 miles of embankment was partially eroded away and another 7.9 miles suffered minor damage where the embankment remained intact but rip rap material was removed or slumped into the channel. Therefore in the sixty-five miles of A.R.R. track situated within the left floodplain of Smoky River, about twenty-three miles suffered some degree of damage.

Air photographs in Appendix A provide an overview of the damaged reaches.

Most of the damaged reaches occurred in situations where the embankment had been placed along the outside of a bend in the river, so that the river approached the embankment at some angle. The increase in velocity at the outside of the bend due to the centrifugal forces developed, plus the fact that the embankment itself had constricted the natural channel section, were primarily responsible for the large erosive forces which destroyed so much track. Photograph F.8 shows a typical damaged reach of the A.R.R. in a situation such as just described.

The mechanism by which the Smoky River was able to erode away the embankment occurred in a number of ways:

(a) Durability, shape, size and gradation of the rip rap material used was inadequate. Although the bank armouring material had been in place only a couple of years, much of it has been severely weathered. The material used for armouring was primarily a sandstone which was placed in such a manner that underlying embankment material was still exposed (see photograph F.2) and could be sucked out through the interstices of the rock.

(b) The armouring material wasn't extended far enough up the slope of the embankment. Flow was able to erode away the bank above the armouring even though the rock on the bottom part of the slope did not move a great deal.

(c) Insufficient volume of armouring material, in particular where an apron should have been provided. In some cases it appeared as if rip rap on the slope might have fallen into a scour hole, thereby exposing the underlying embankment material.

(d) Local inflow sometimes couldn't be handled by the culverts provided through the embankment. In this situation water piled up behind the track had either overtopped it or flowed downstream along the embankment, eroding it out in the process. Photograph F.5 is an example of a situation where local inflow overtopping the track was beginning to scour out the embankment.

(e) The Smoky River did overtop the track at some locations and where the armouring was poor or non-existent the overflow would have scoured away the embankment.

III. The Alberta Resources Railway track crosses over to the left floodplain at Mile 104, is maintained within this floodplain to Mile 169, where it then leaves the floodplain and crosses over to the right valley wall. The drainage area at Mile 104 is about 1,500 square miles and at Mile 169 is about 2,600 square miles. Within this reach the two major tributaries are the Muskeg River (Mile 112, 388 square miles) and Sheep Creek (Mile 115, 361 square miles).

The 1972 Smoky River flood which caused the destruction of some track between Mile 104 and 169 was a result of a large amount of rainfall which occurred primarily in a 24-hour period during June 11 and 12 in the headwater basins of the Smoky River. The storm was centered on Nose Mountain, south-west of Grande Prairie and extended south over the Wapiti, Kakwa, Cutbank, Sheep, Muskeg and upper Smoky basins. It was estimated that a peak discharge of 85,000 cfs passed through the Smoky River below Sheep Creek and this value was used in the hydraulic analysis of the Smoky channel in Appendix C.

Little discharge data are available for the Smoky River near Grande Cache so a regional flood-frequency analysis was attempted in order to establish how often one might expect a recurrence of the 1972 flood. As a result of this work it was concluded that this year's flood on the Smoky River below Sheep Creek had a probability frequency of at least once in fifty years but not likely greater than once in one-hundred years on the average. Attempting to suggest any more specific frequency value would not be acceptable considering the amount of data at hand.

IV. A hydraulic analysis of the Smoky River channel provided a means of designing four different rock gradations for bank armouring. It was assumed that any future protection works on the A.R.R. embankment would utilize first class rip rap material as armouring (vis. limestone rock) and the existing sandstone rip rap would be considered redundant in terms of being useful.

Lengths of embankment thought to require protection are delineated on the air photographs in Appendix A by means of a heavy, black line. The class of rock required is also provided (see Appendix D for detailed description of rock classes). In general the protection schemes considered involve bank armouring, spurs, dikes and channel excavation.

V. An estimate has been made of the cost to completely repair the damaged portions of the A.R.R. It was assumed that the rock source for rip rap material would be an existing limestone quarry at Cadomin, some 300 rail miles from the middle of the damaged reaches below Mile 104. Further it was felt that the C.N.R. would be able to haul this rock to the site using their equipment, at an "at-cost" price of five dollars

per cubic yard or that the "at-cost" price would be about three cents per ton-mile. Total unit price of buying, blasting, loading, transporting and placing rock has been set at nine dollars per cubic yard.

Following is a detailed breakdown of the total repair cost:

| | |
|---|---|
| Bank armouring (including all aspects of getting the rock in place) | $14,500,000 |
| Embankment reconstruction | 4,370,000 |
| Culvert replacement | 130,000 |
| Spur embankment construction | 300,000 |
| Channel Excavation | 300,000 |
| Sub-total | $19,600,000 |
| Engineering and Contingencies (15%) | 3,000,000 |
| Total | $22,600,000 |

VI. The possibility of controlling the flood peak by means of a flood storage dam was investigated. A twenty mile reach above Mile 104 (A.R.R.) along the Smoky River was investigated for possible dam-sites. The site selected was immediately above the highway bridge on the road between Grande Cache and the McIntyre-Procupine Co. mine-site. Only a very broad design approach was taken during an office study because of data and time restrictions, which should be considered when applying the conclusions of the investigation.

About 215,000 acre-feet of storage would be required above the proposed dam to protect the Alberta Resources Railway against a flood similar to that experienced in June, 1972. Typically a dam 200 feet high having a crest length of 2500 feet would be required. The reservoir

at maximum pool elevation would extend over 2,500 acres. Discharges below the dam would reach a maximum of 35,000 cfs usually after the passage of the floods from downstream basins (eg. Sheep Creek, Muskeg River). Assuming that storage releases began two days after peak inflow during the 1972 flood, and routing of the inflow hydrograph through the reservoir, it was estimated that the maximum discharge below Sheep Creek would have been in the area of 42,000 cfs, or one-half the natural peak. This amount of flow would still require that some bank protection measures be instituted along the A.R.R. embankment, although the level of protection required would be much less than that envisioned in Appendix D.

Gross estimated cost is in the order of $65 million dollars. A dam in this price bracket appears to offer little potential benefit beyond flood control, and would likely have serious implications with respect to the ecology of the area.

VII. Conclusions; direct application of bank protection and river-training works would offer the cheapest and most reliable method of protecting a reconstructed Alberta Resources Railway grade. This cost has been estimated to be about 23 million dollars but possibly after more field and design information is collected some potential savings would arise. For instance, a closer source of adequate rip rap material might be found; or the amount of apron rock thought necessary could be reduced if it were found that bedrock was within a few feet of the bed.

# APPENDIX A

## Damaged Sections of Alberta Resources Railway

# APPENDIX A

## Damage Along Alberta Resources Railway

A.1 Types of damage; the physical condition of the Alberta Resources Railway was observed by air photo interpretation and some limited field reconnaissance observations. Three degrees of damage were delineated and transcribed on the air photographs provided in this Appendix. The different damaged reaches have been separated by using three different colours, each meaning the following:

Yellow; minor damage - some or all of the rip rap removed by the flood but the embankment essentially intact.

Green; intermediate damage - all or portion of rip rap removed and embankment partially removed.

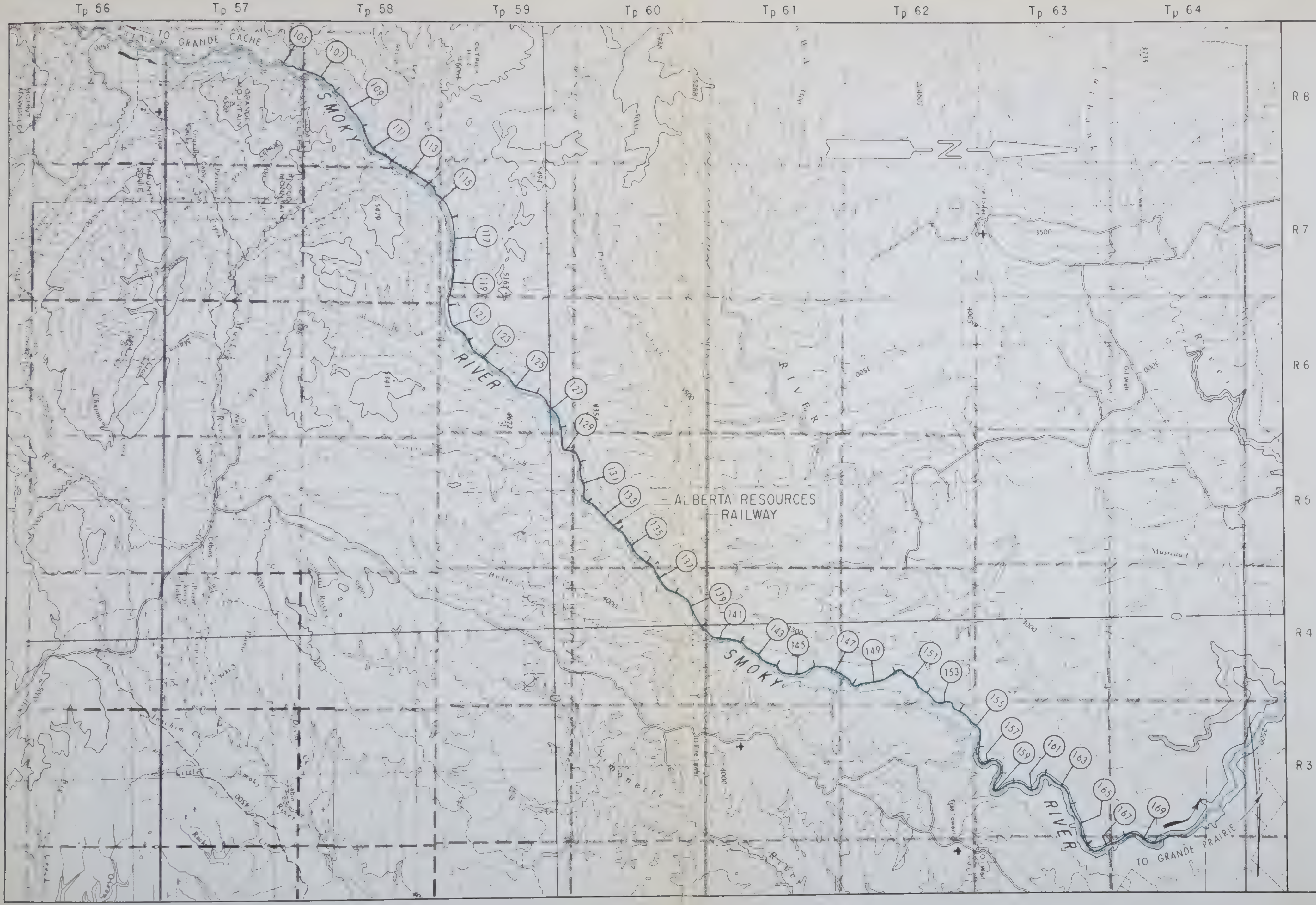
Red; major damage - complete destruction of embankment. Flood flow has removed rip rap and eroded through embankment to retake its original channel position.

A.2 Summing up the various damaged reaches from the photographs resulted in the observation that:

- 7.9 miles of embankment suffered minor damage
- 7.8 miles of embankment suffered intermediate damage
- 7.6 miles of embankment suffered major damage.

Therefore a total of 23.3 miles of track was damaged to some degree.

Other types of damage occured but weren't tabulated; such as erosion of the left side of the embankment by water from small tributaries being forced to run parallel to the embankment or over it because flow-through culverts could not handle the flow, or rock rip rap and embankment material removed from spur noses.



# LOCATION PLAN

SCALE 1" = 4 MILES

MILES 4 3 2 1 0 1 2 3 MILES

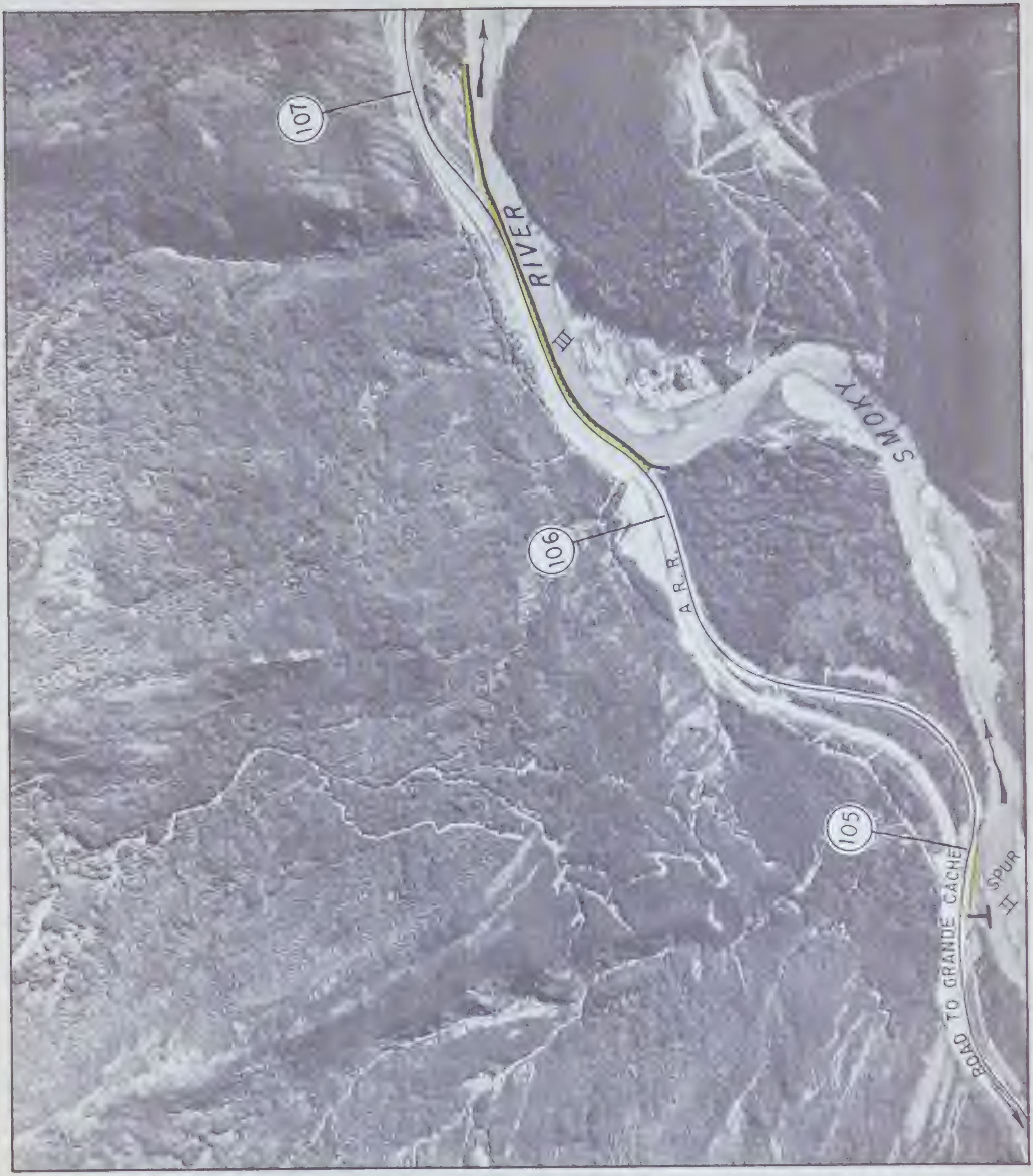
# ALBERTA RESOURCES RAILWAY

# SMOKY RIVER BANK PROTECTION STUDY

*LEGEND:*

Roads:

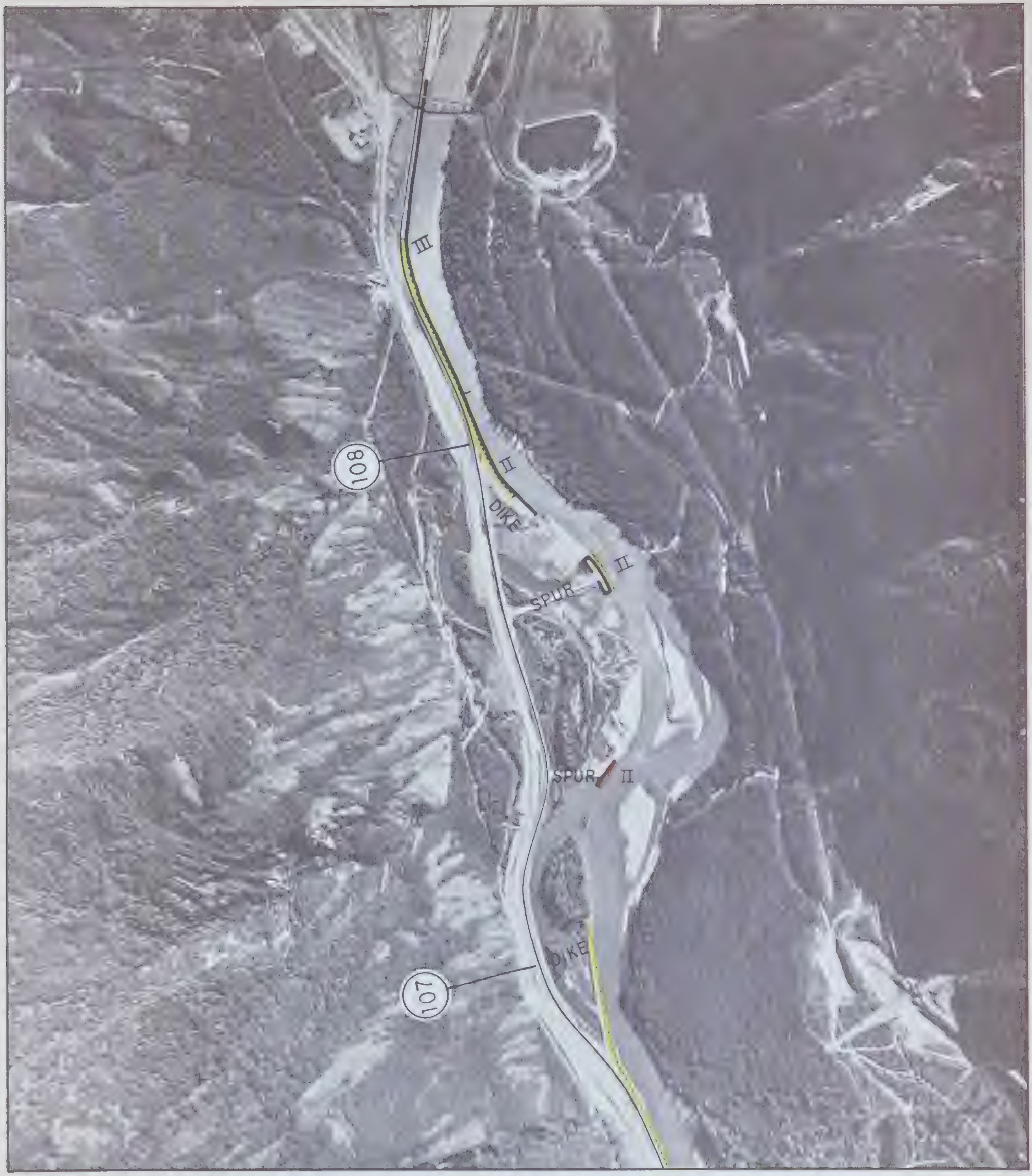
| | |
|---|---|
| All weather | ——— |
| Dry weather | ═══ |
| Cart track | — — — — |
| Trail or portage | - - - - - |
| Railway, normal gauge, single track | —+—+—+— |
| Mine or Open cut | ⚒ |
| Horizontal control point, with elevation | 4607 △ |
| Bench mark, with elevation | B M → |
| Building | ■ |
| River with bridge | |
| Stream, intermittent or dry | |
| Lake intermittent; indefinite | |
| Marsh or Swamp | |
| Depression contours | |
| Contour interval 100 feet | — 3000 — |
| Circled nos. Are mileages along track | (111) — |



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

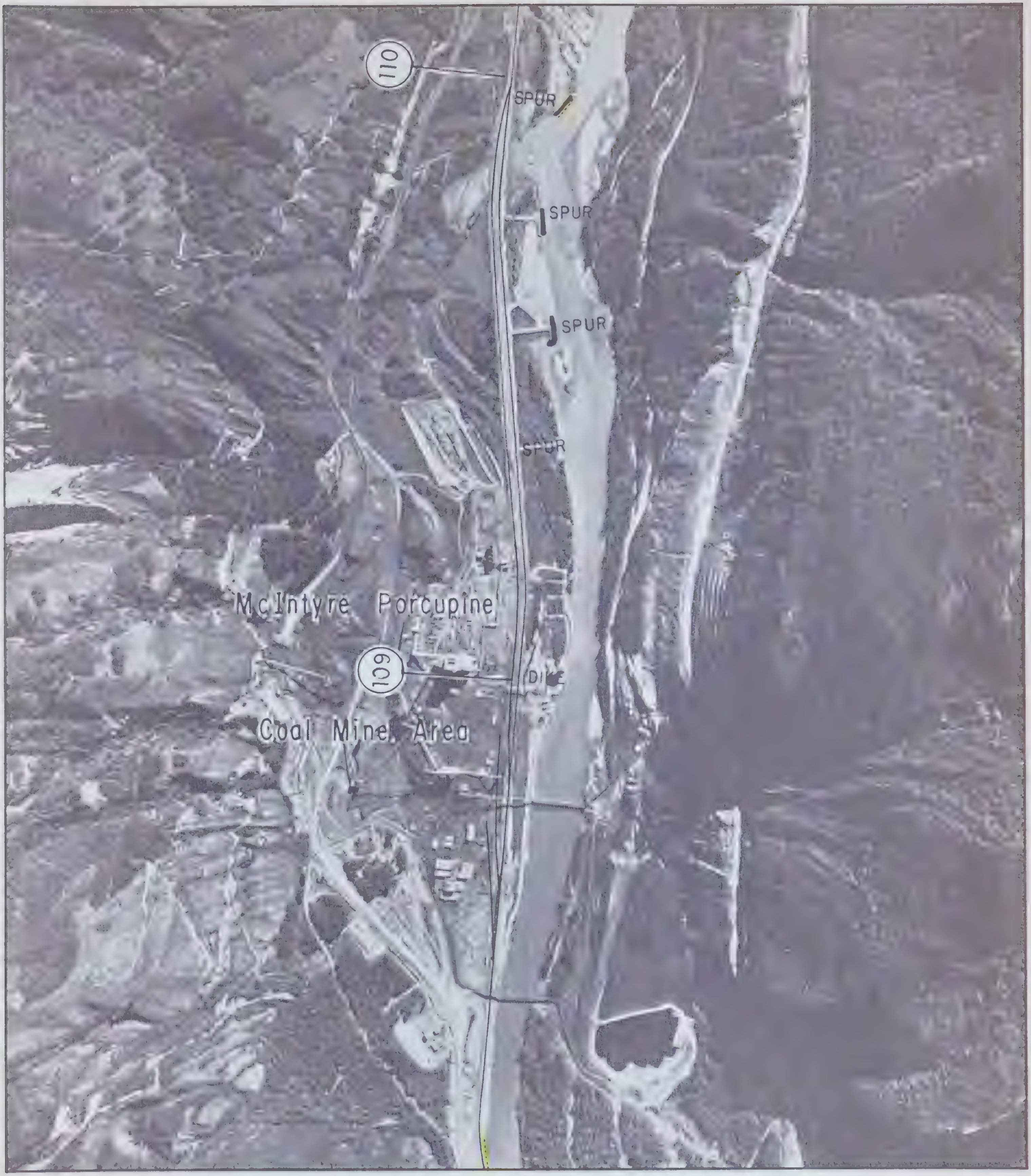
PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 1400' (APPROX.)

NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE. CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.



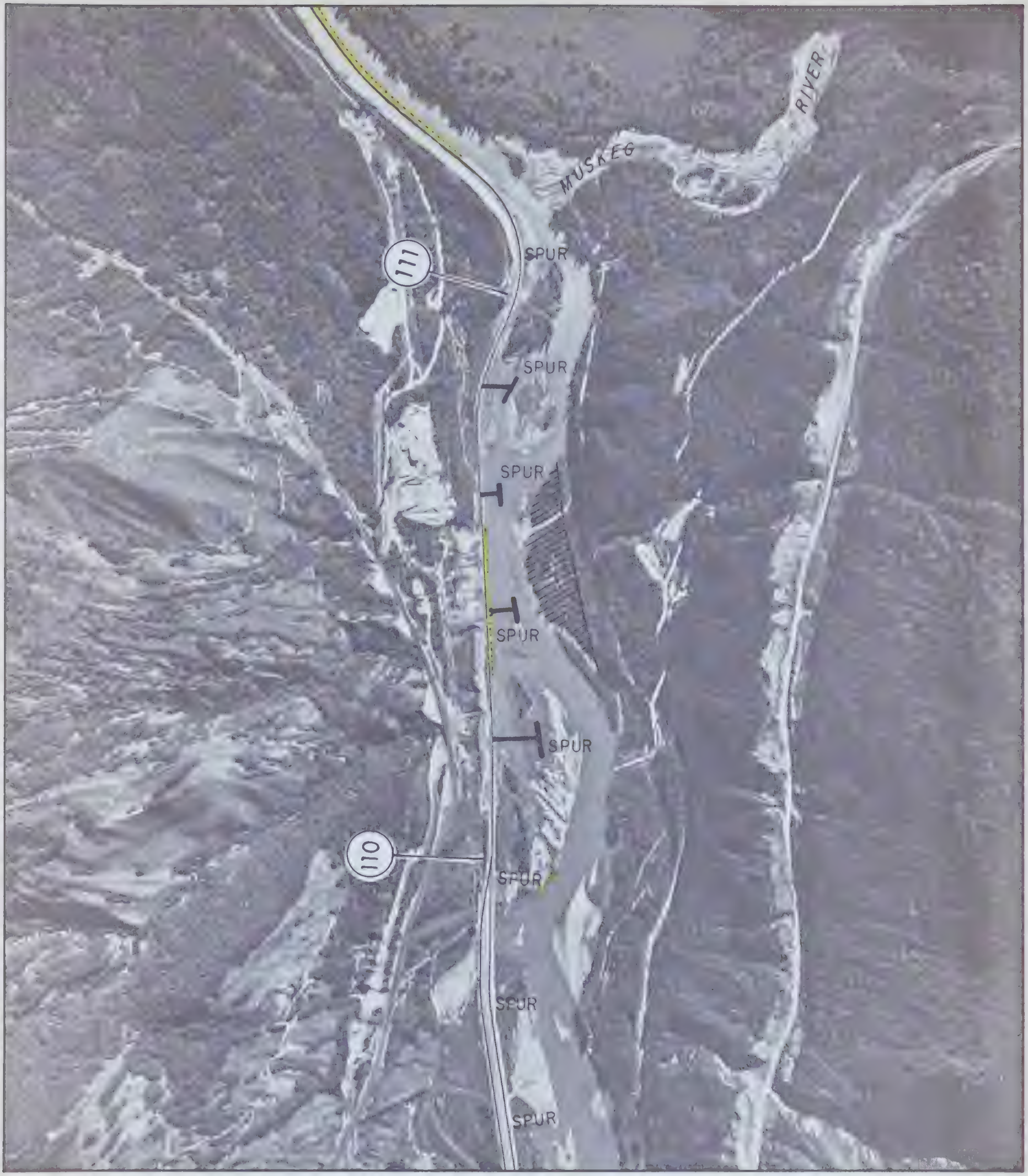
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1 : [illegible] ([illegible])



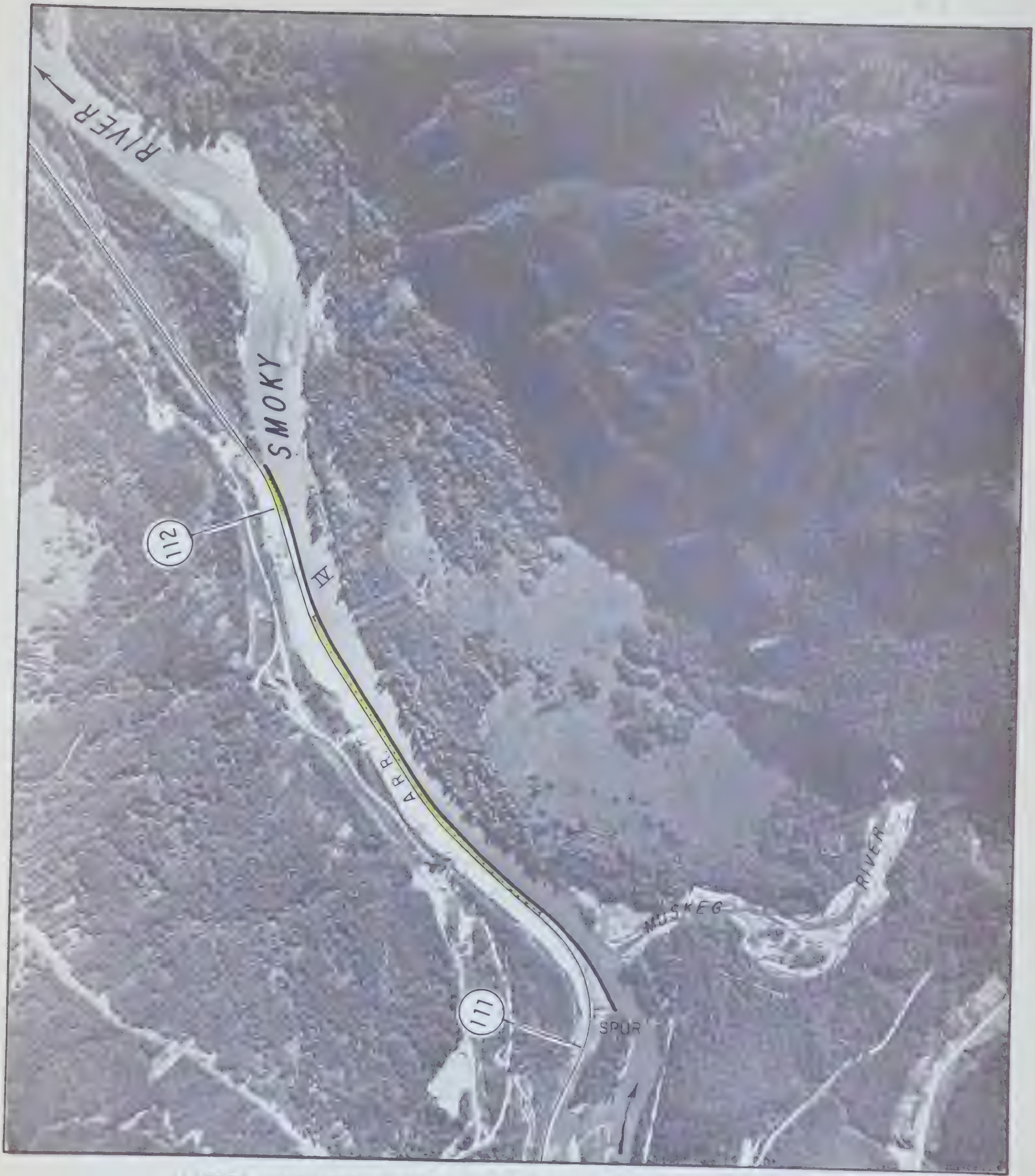
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1 = 12500 (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

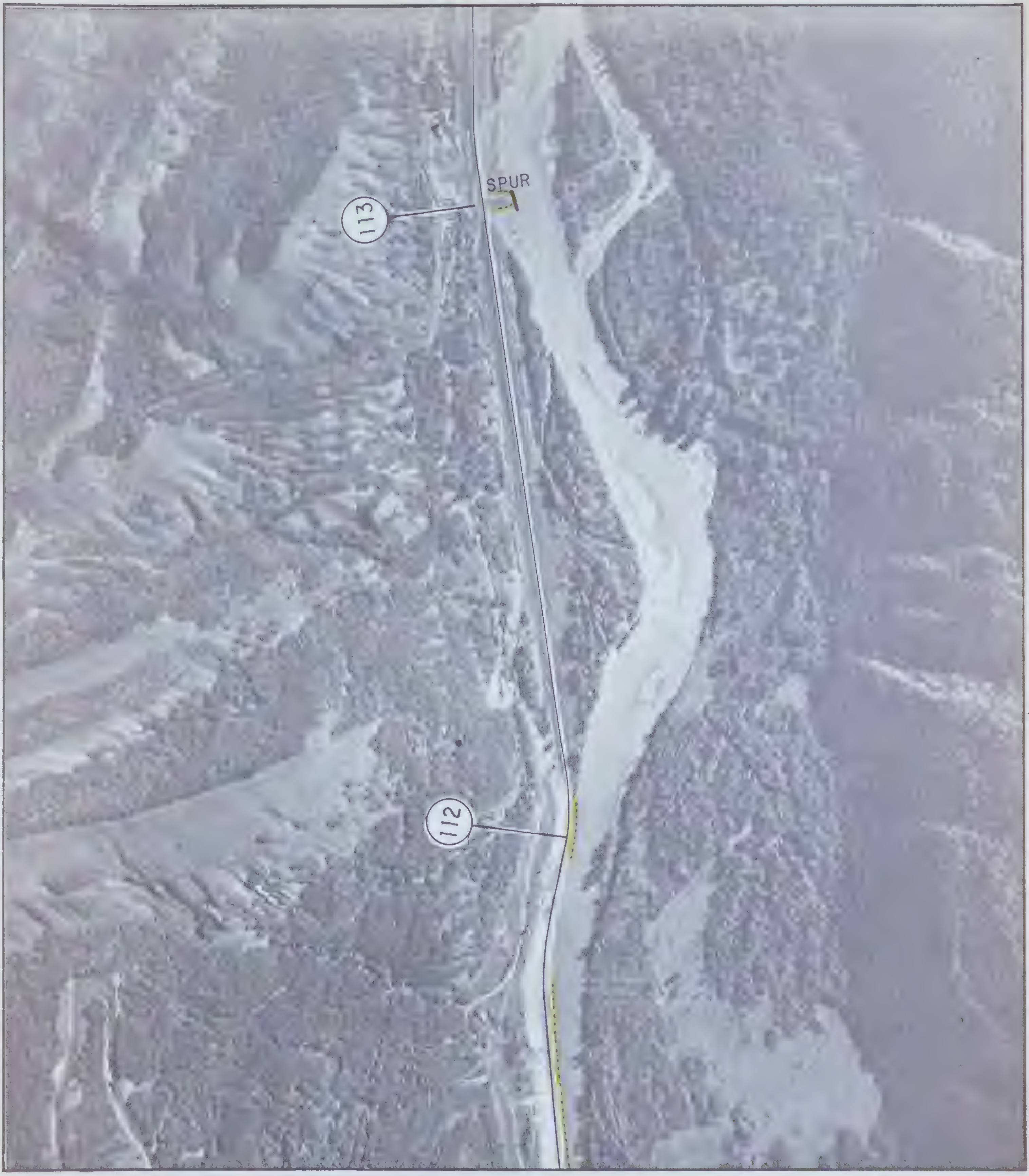
PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 1250' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

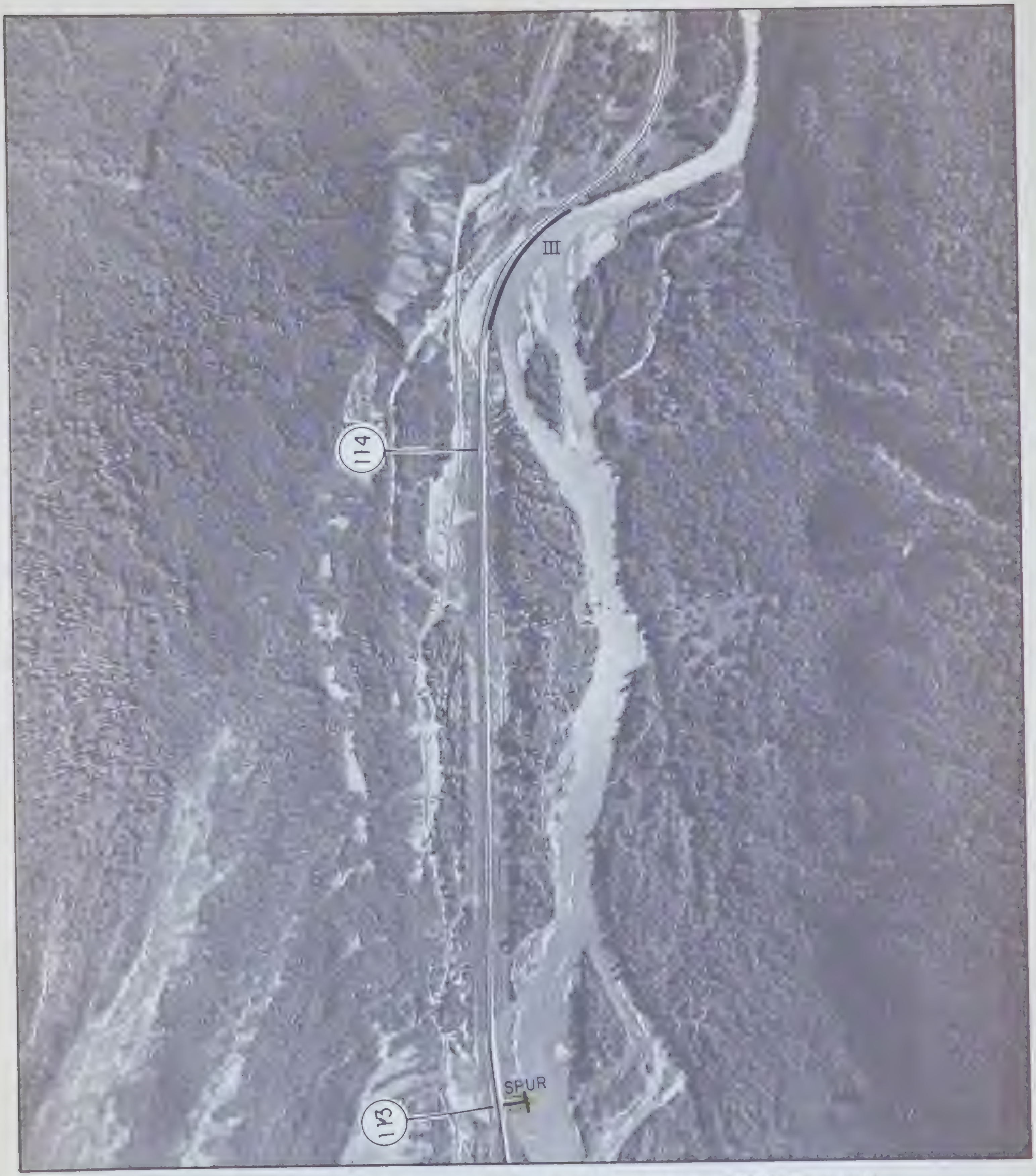
PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 1150' (APPROX.)

NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE
CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS



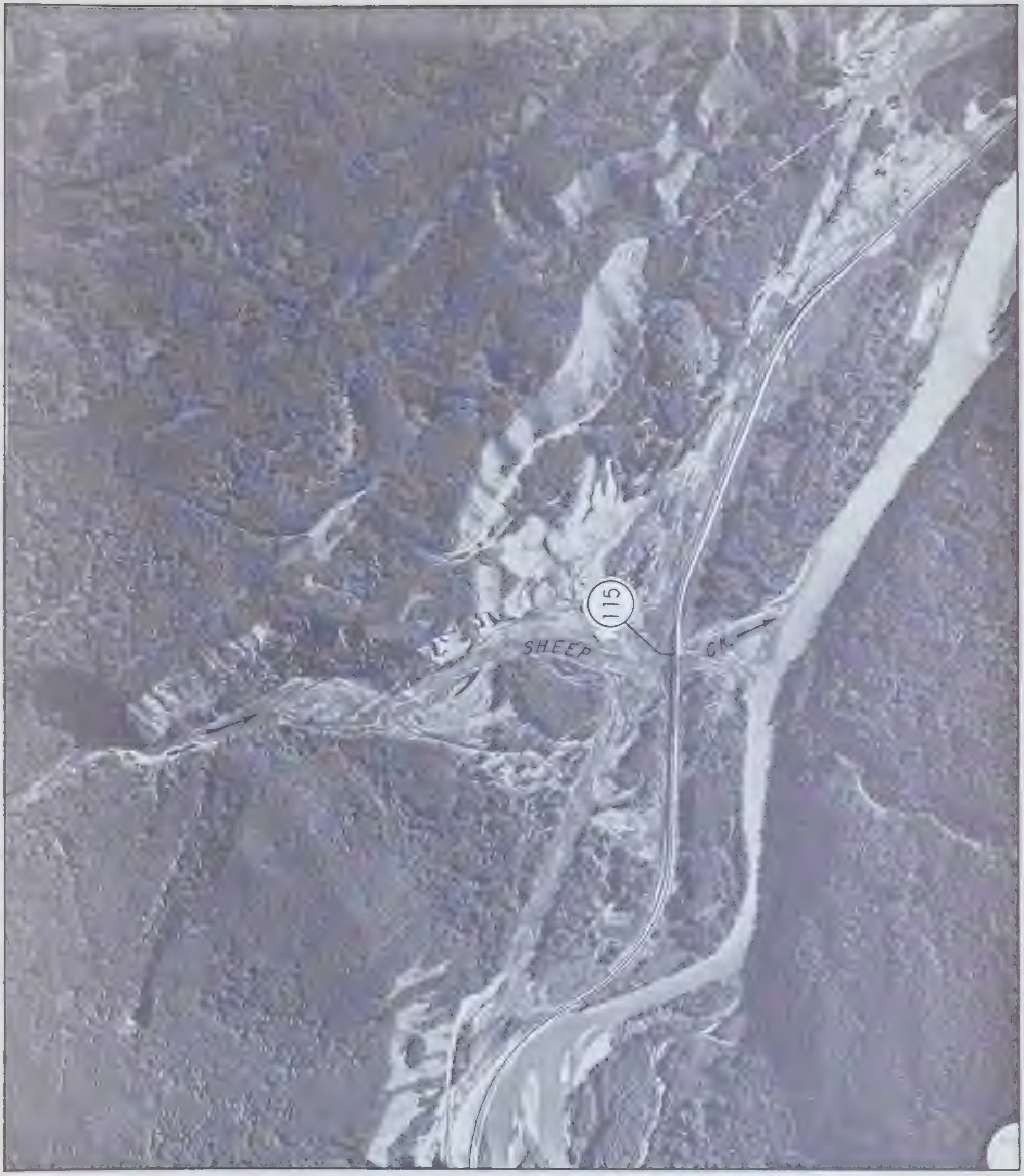
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 1100' (APPROX.)



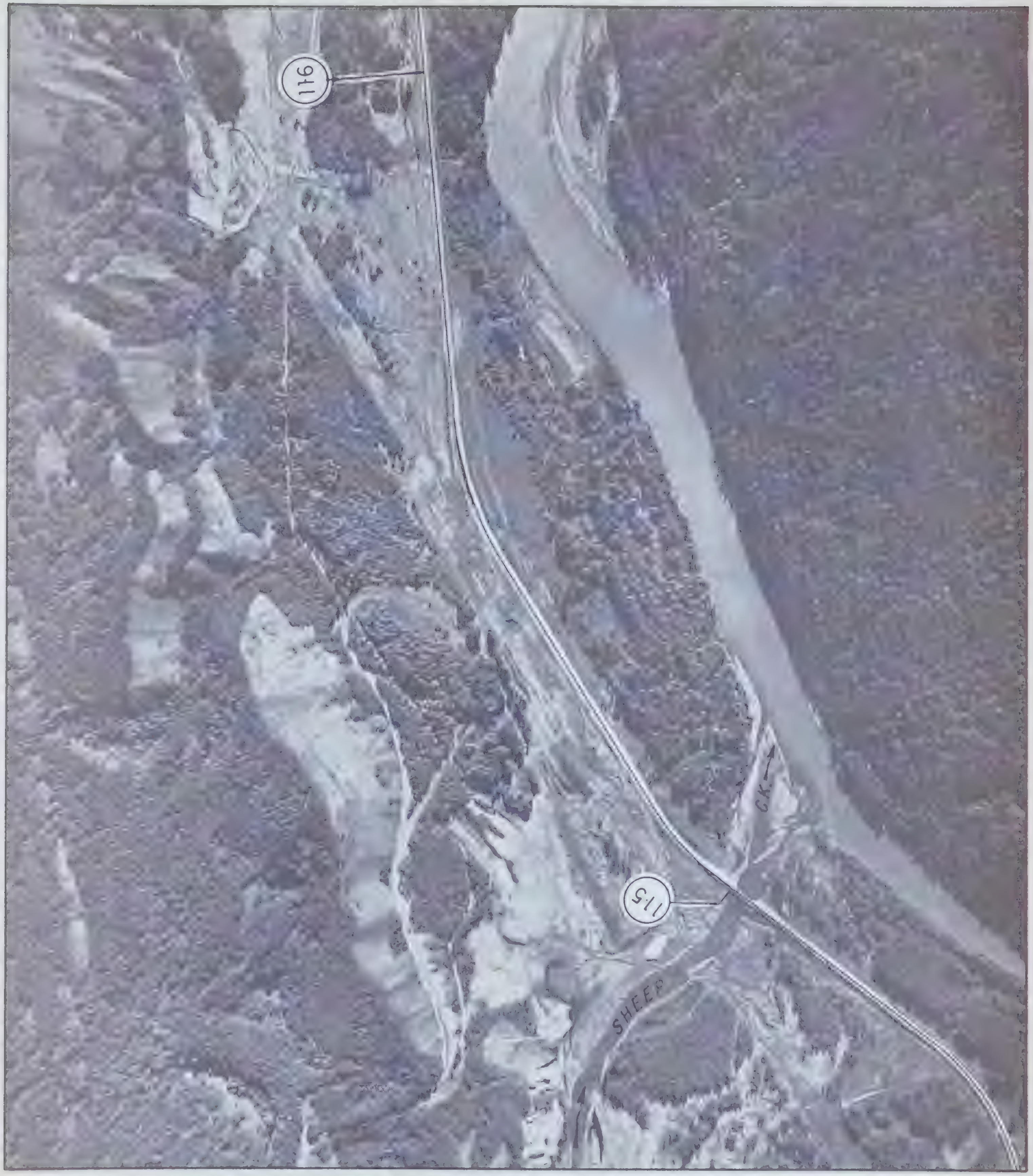
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1975   SCALE 1" = 1100' (APPROX.)



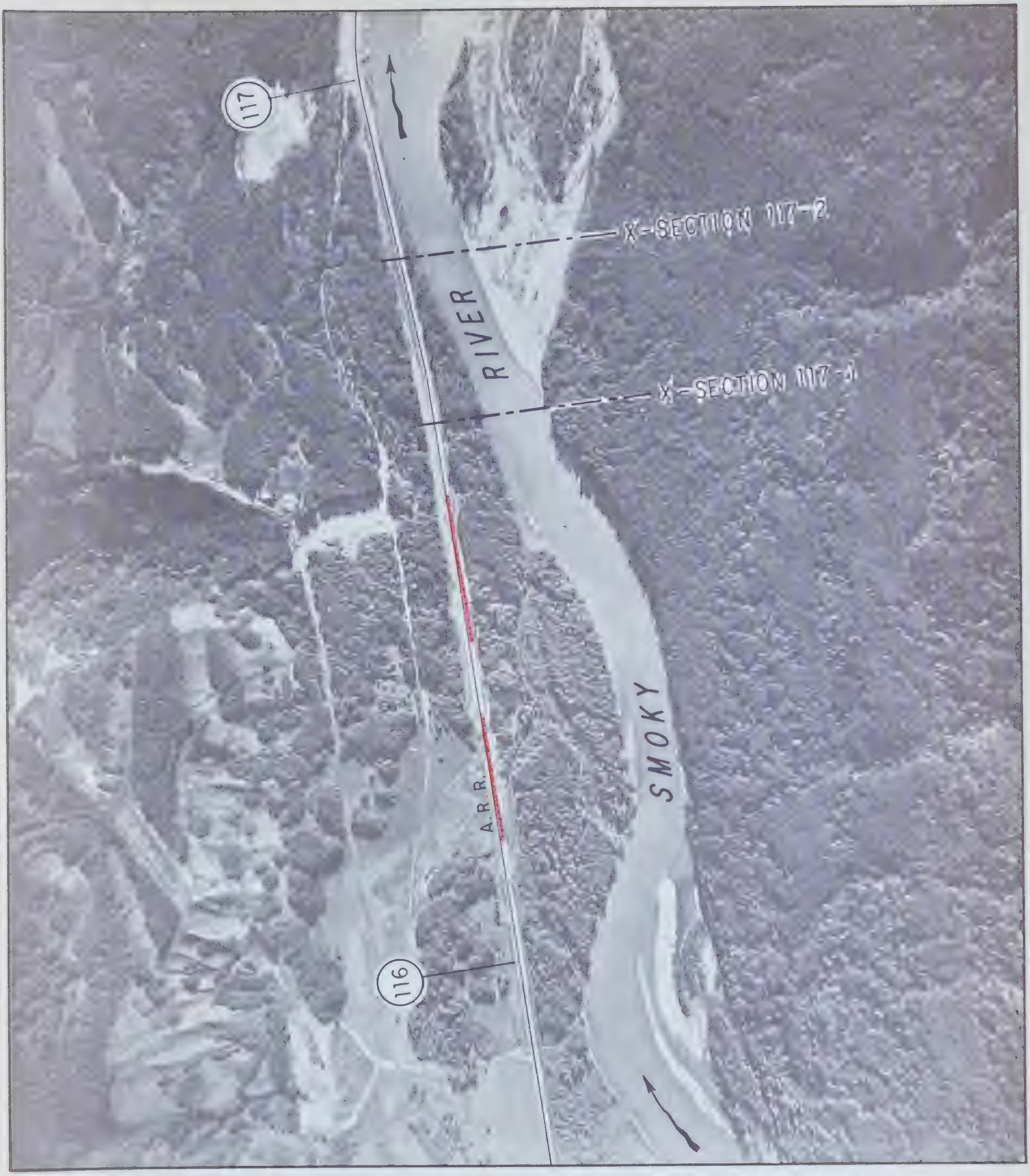
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1982   SCALE 1" = 1100' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 500' (APPROX.)

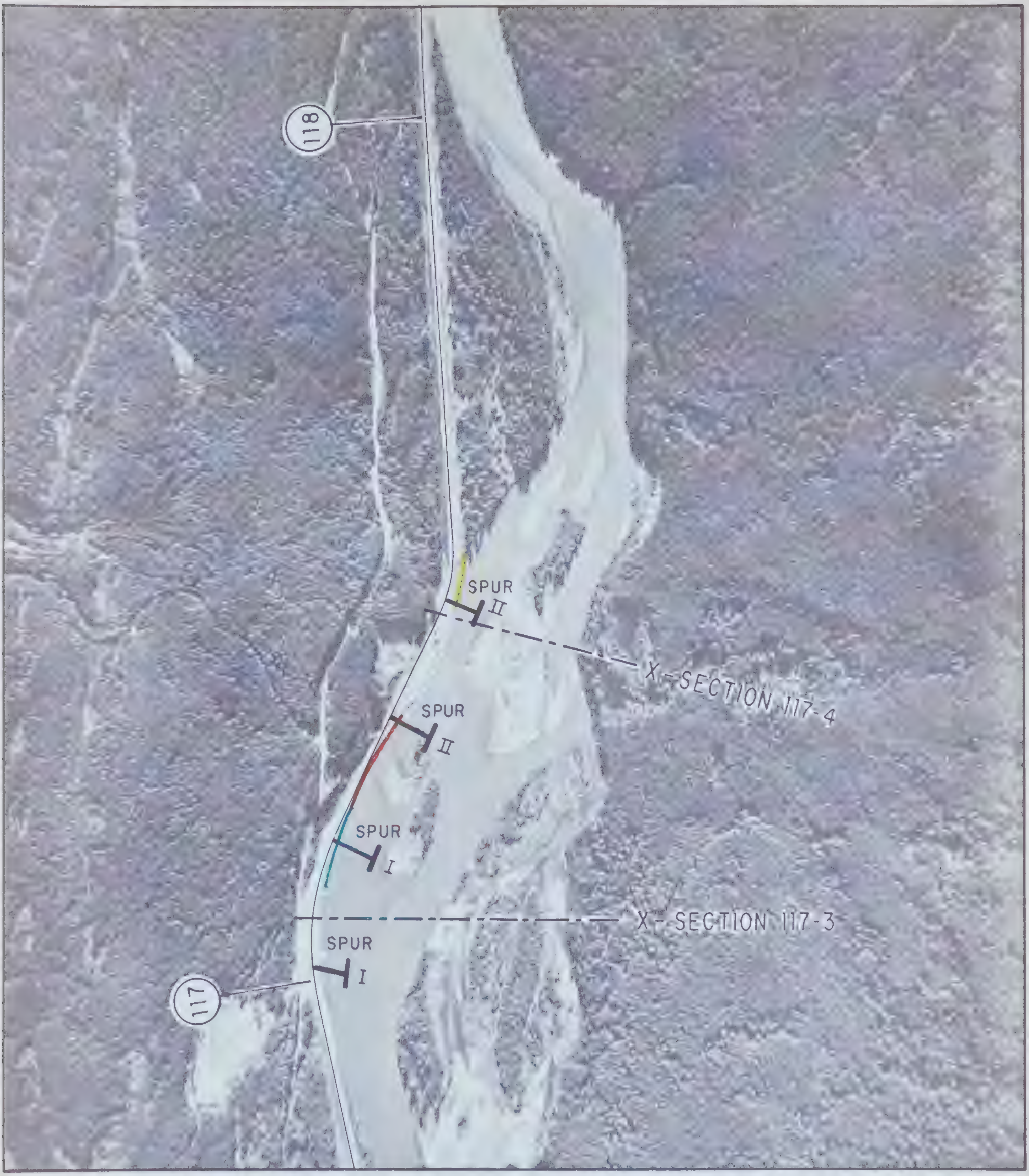


ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)

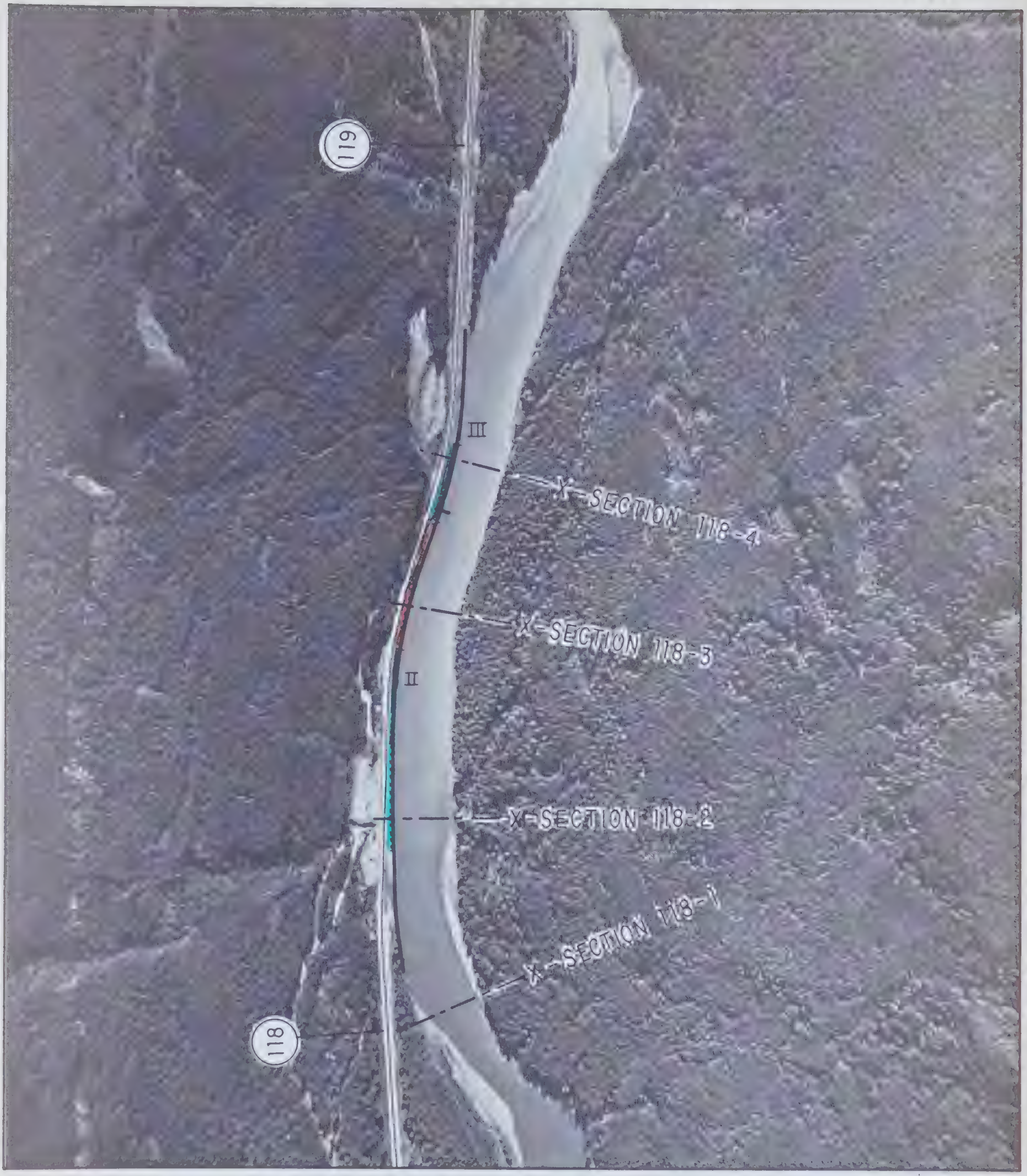
NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.

NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972)    DISCHARGE ABOUT 2000 C.F.S



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

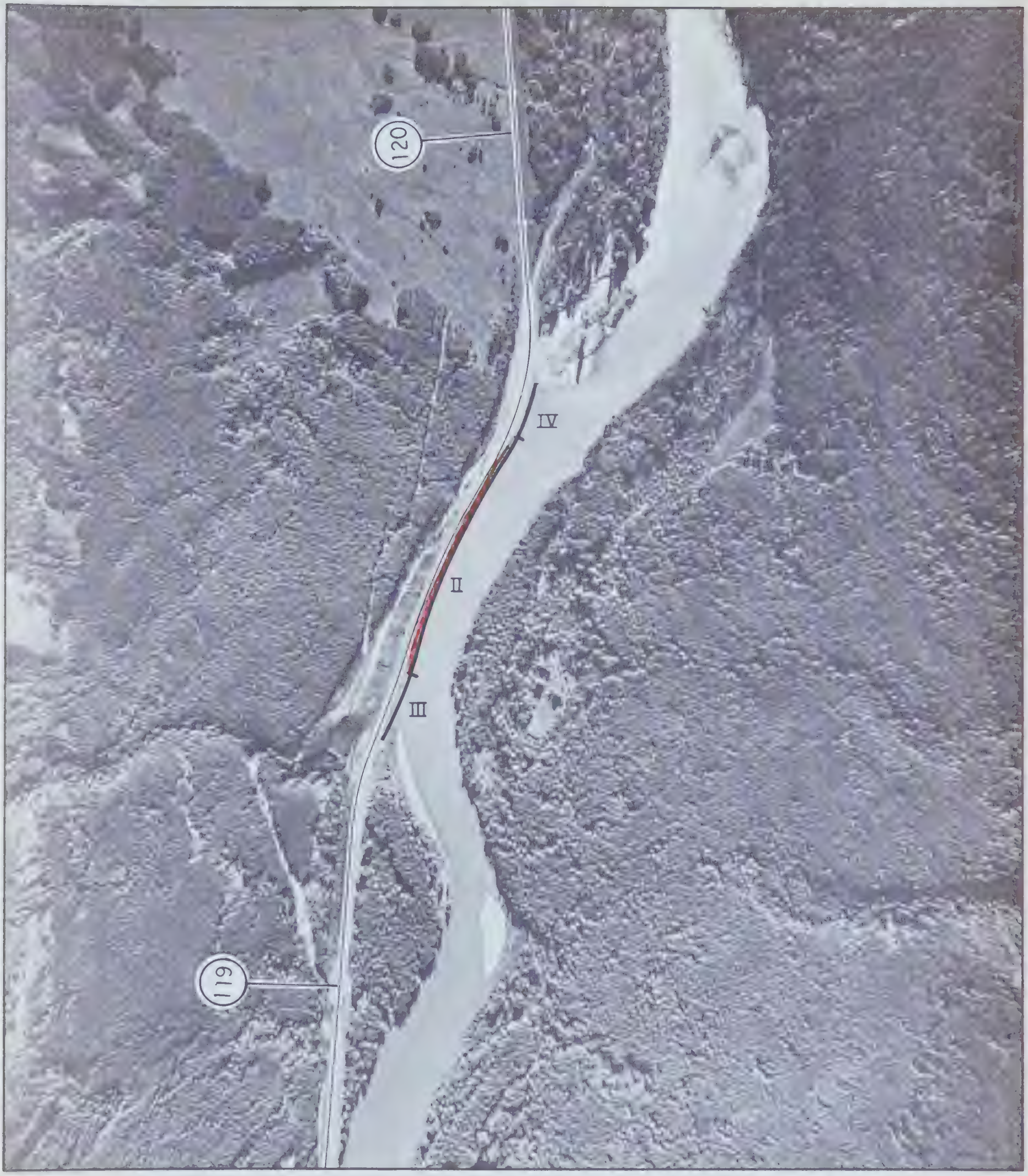
PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)
NOTE    SURVEYED X-SECTIONS (NOVEMBER 1972)    DISCHARGE ABOUT 2000 C.F.S



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

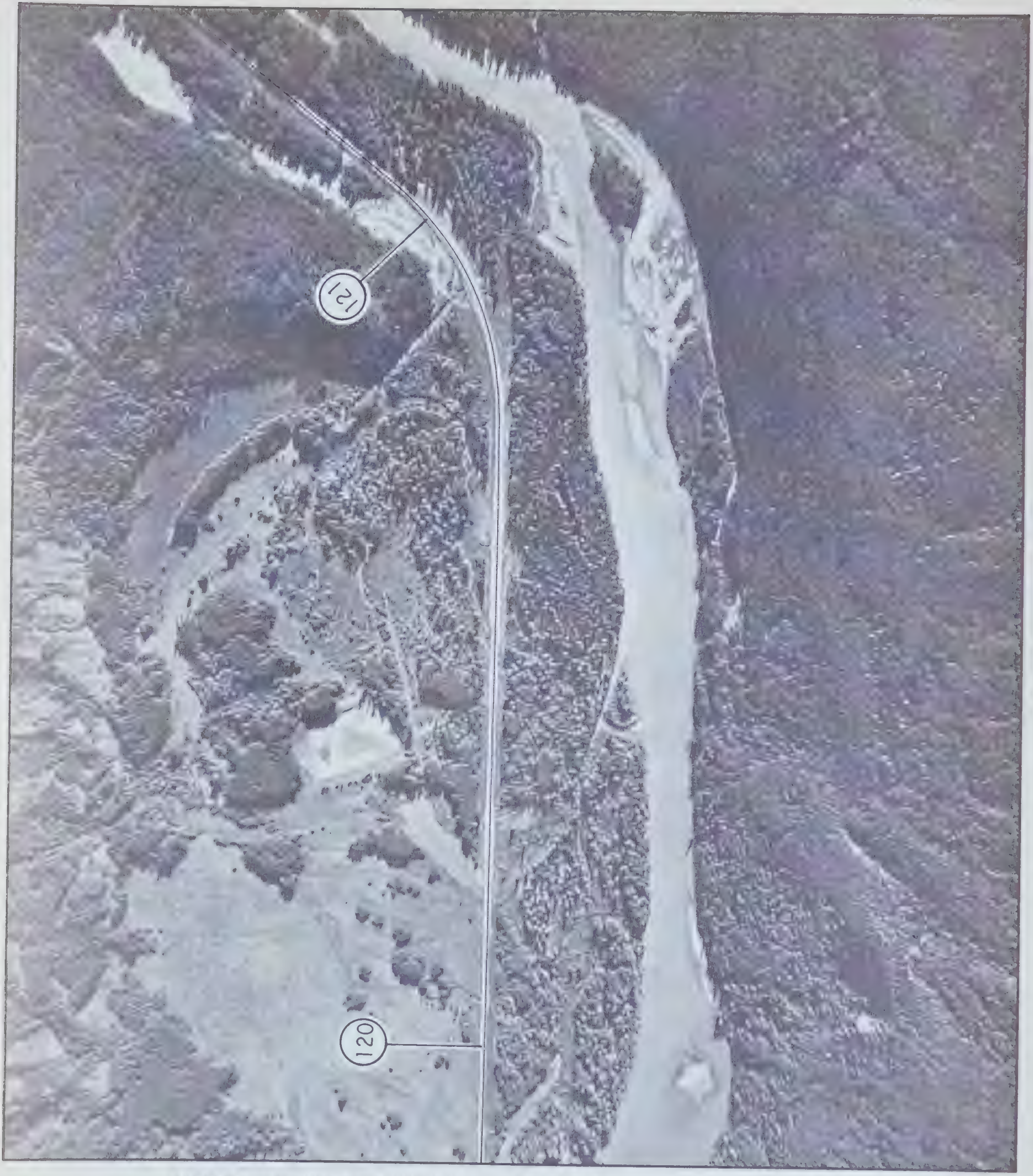
PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)

NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972) DISCHARGE ABOUT 2000 C.F.S.



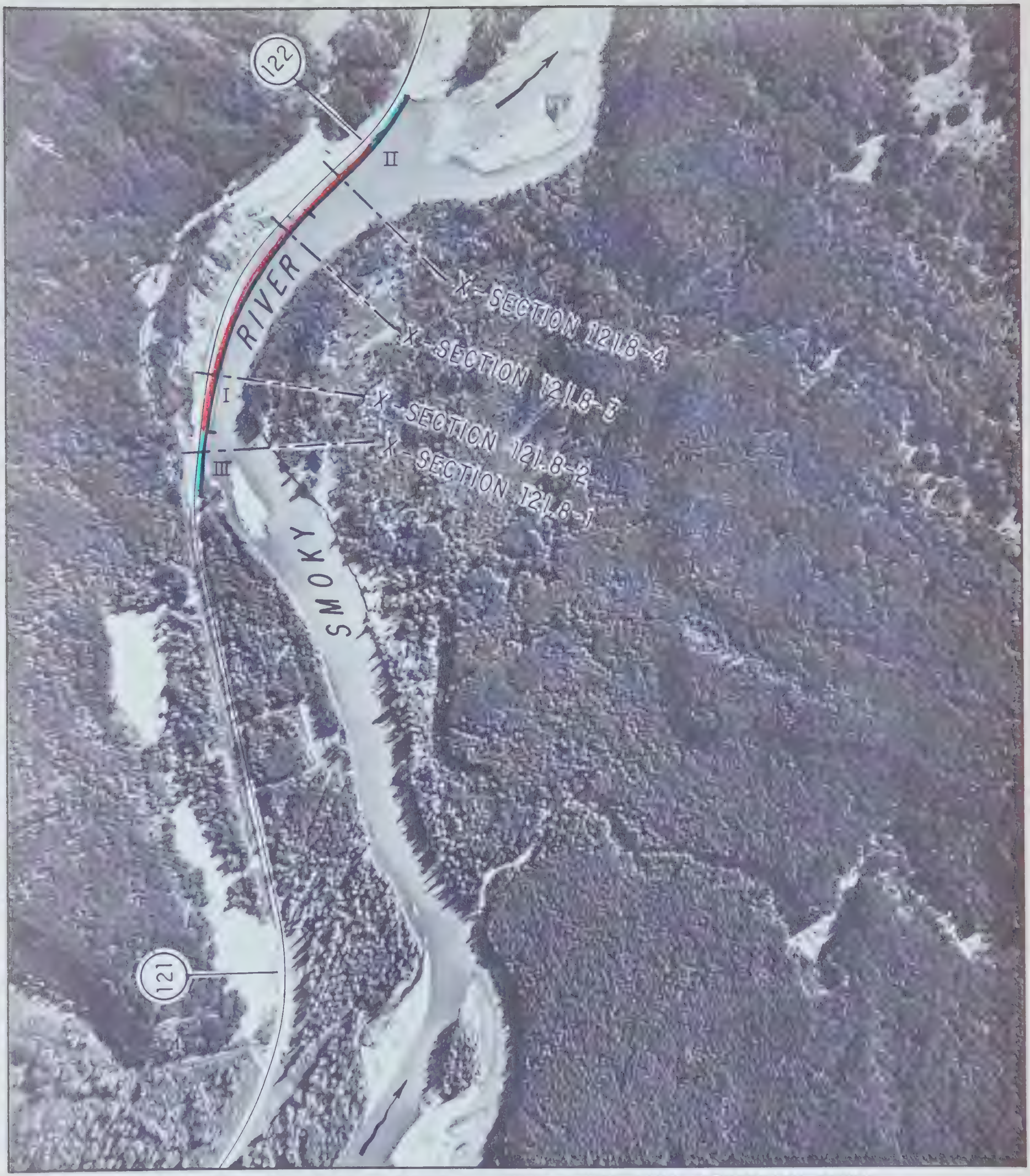
ALASKA REST[illegible]ED RAILWAY - SNOW RIVER BANK PROTECTION STUDY

PHOTOGRAPH TAKEN JULY 1, [illegible]   SCALE 1" = 300' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 500' (APPROX.)

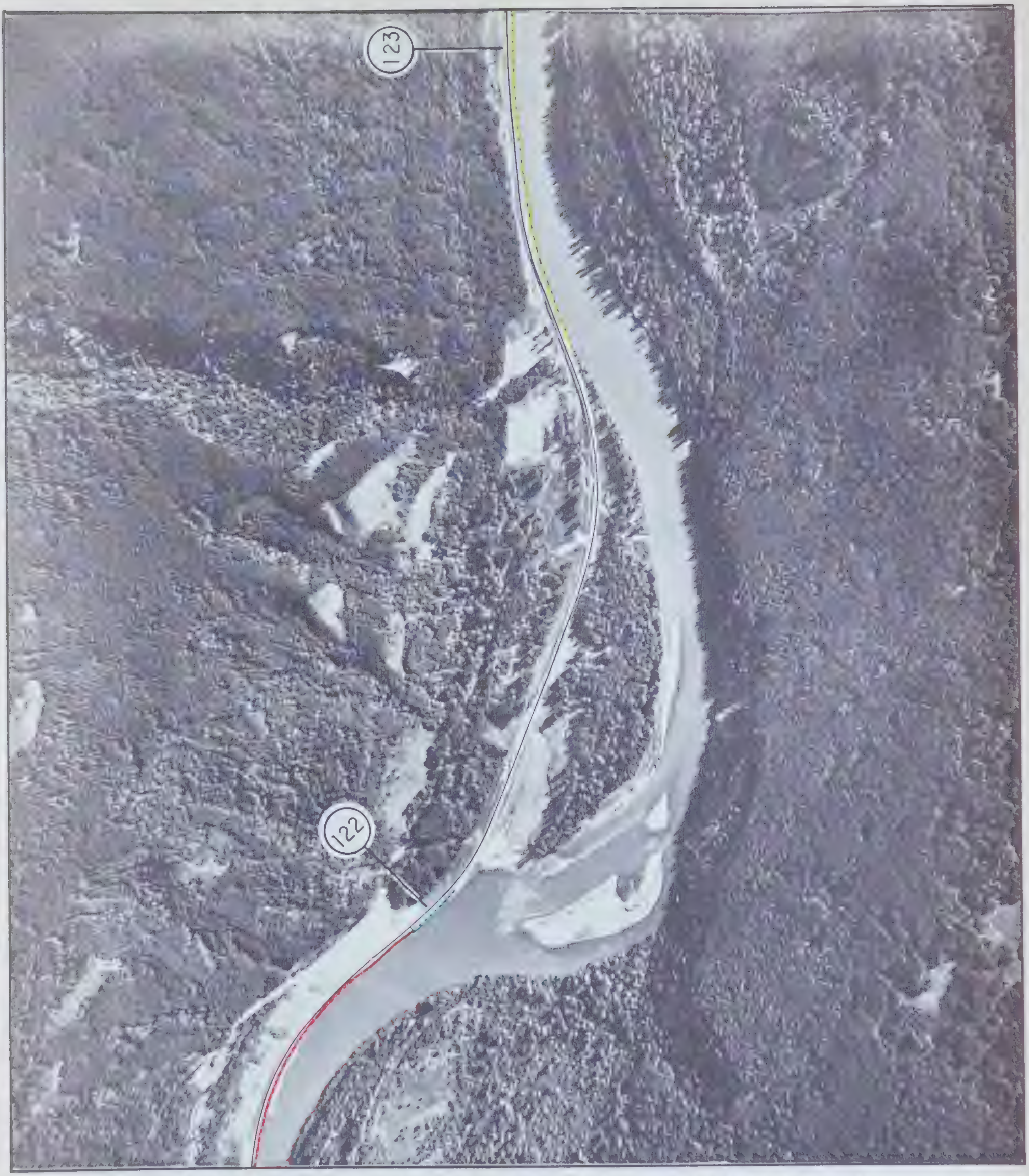


ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPH TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)

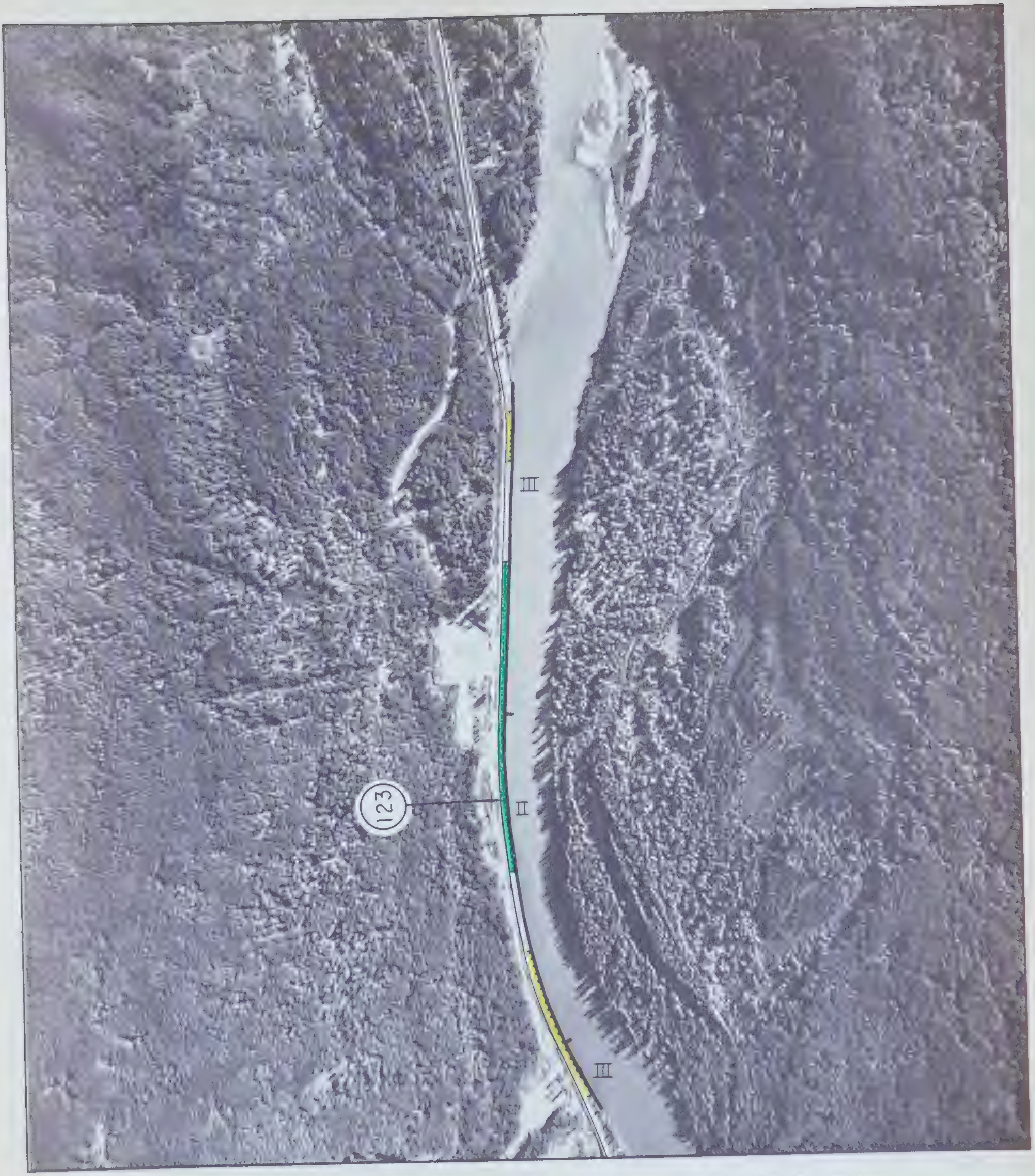
TE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE. CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS

E SURVEYED X-SECTIONS (NOVEMBER 1972). DISCHARGE ABOUT 2000 C.F.S.



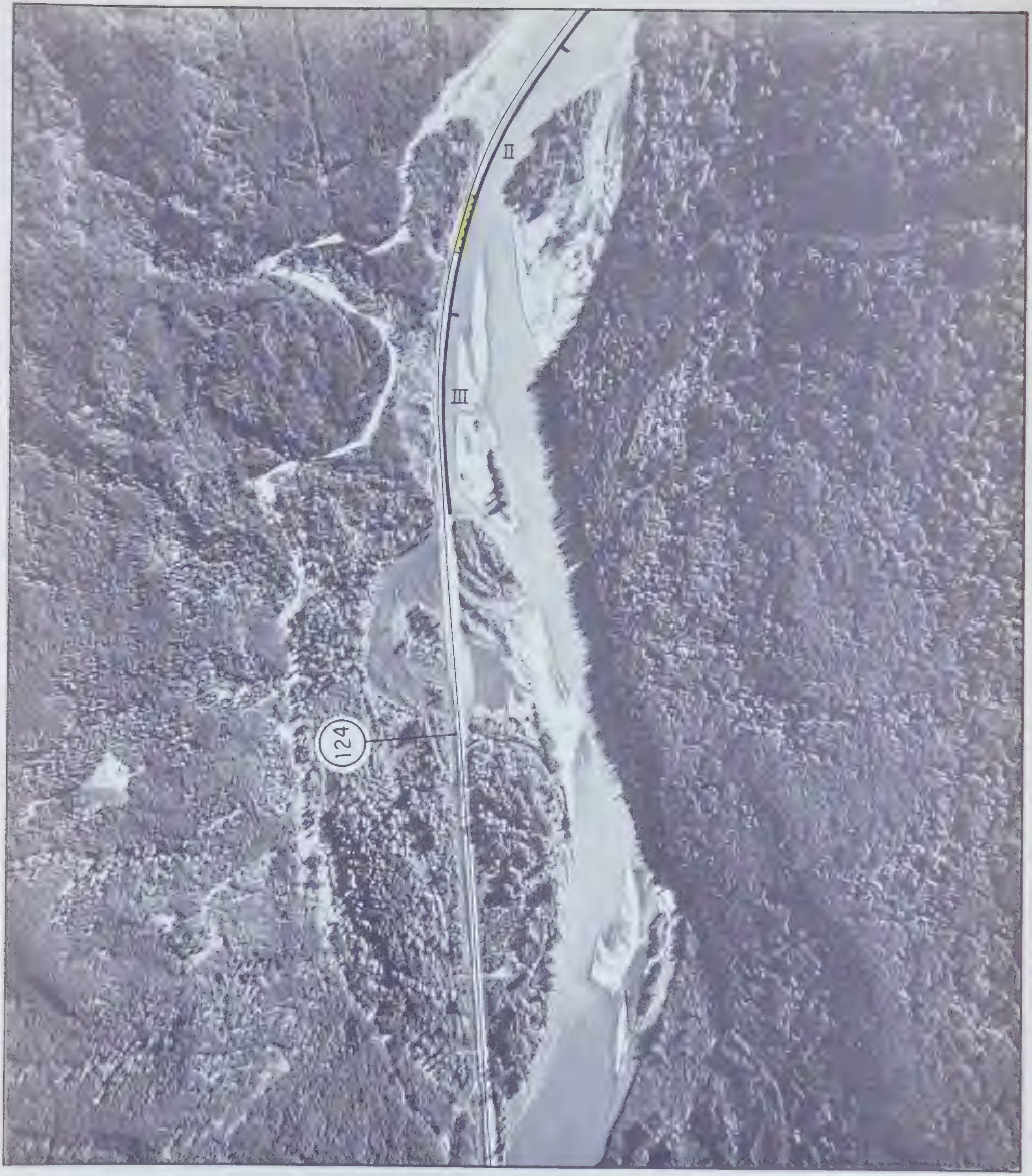
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 500' (APPROX.)



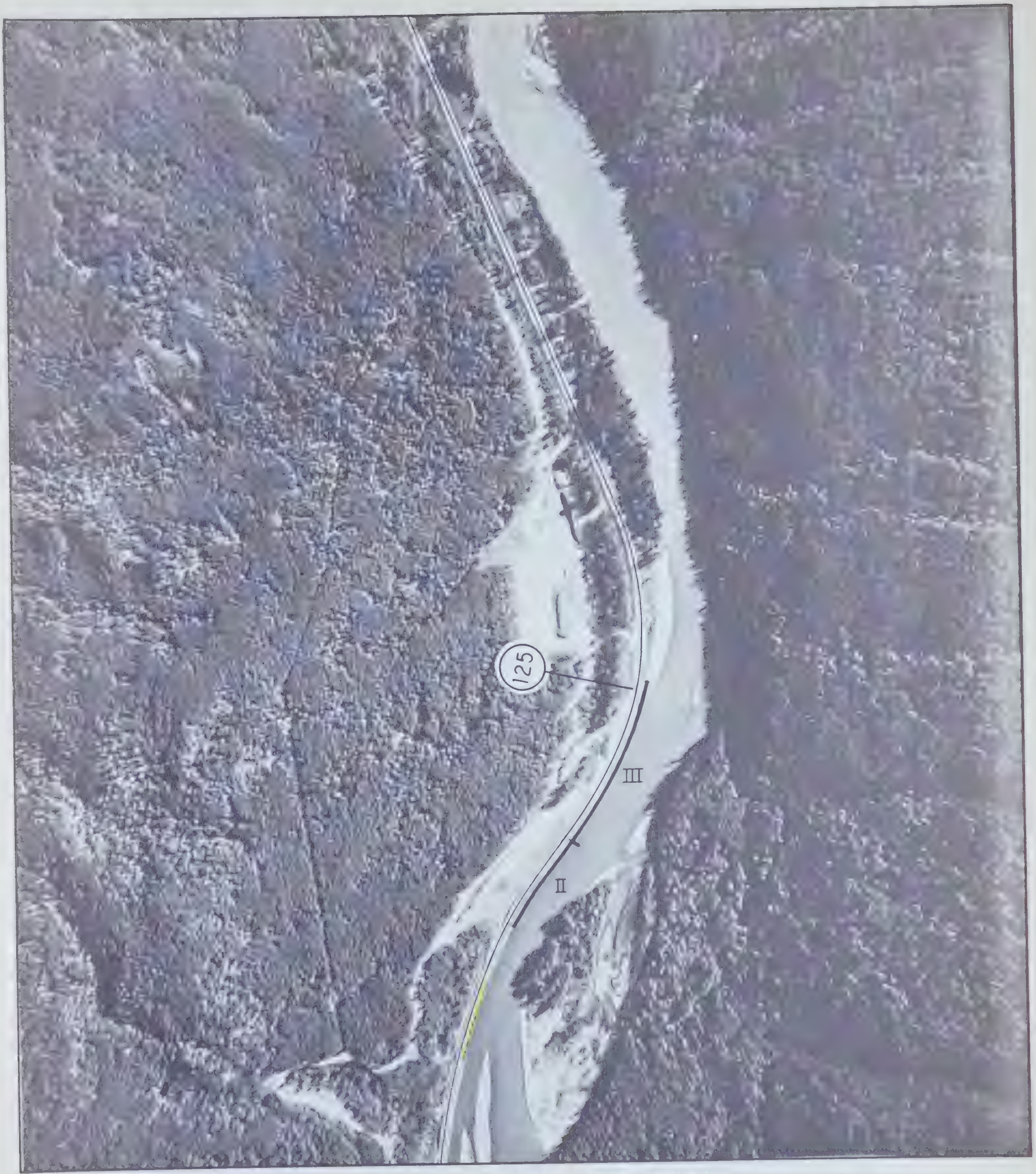
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972   SCALE 1" = 300' (APPROX.)



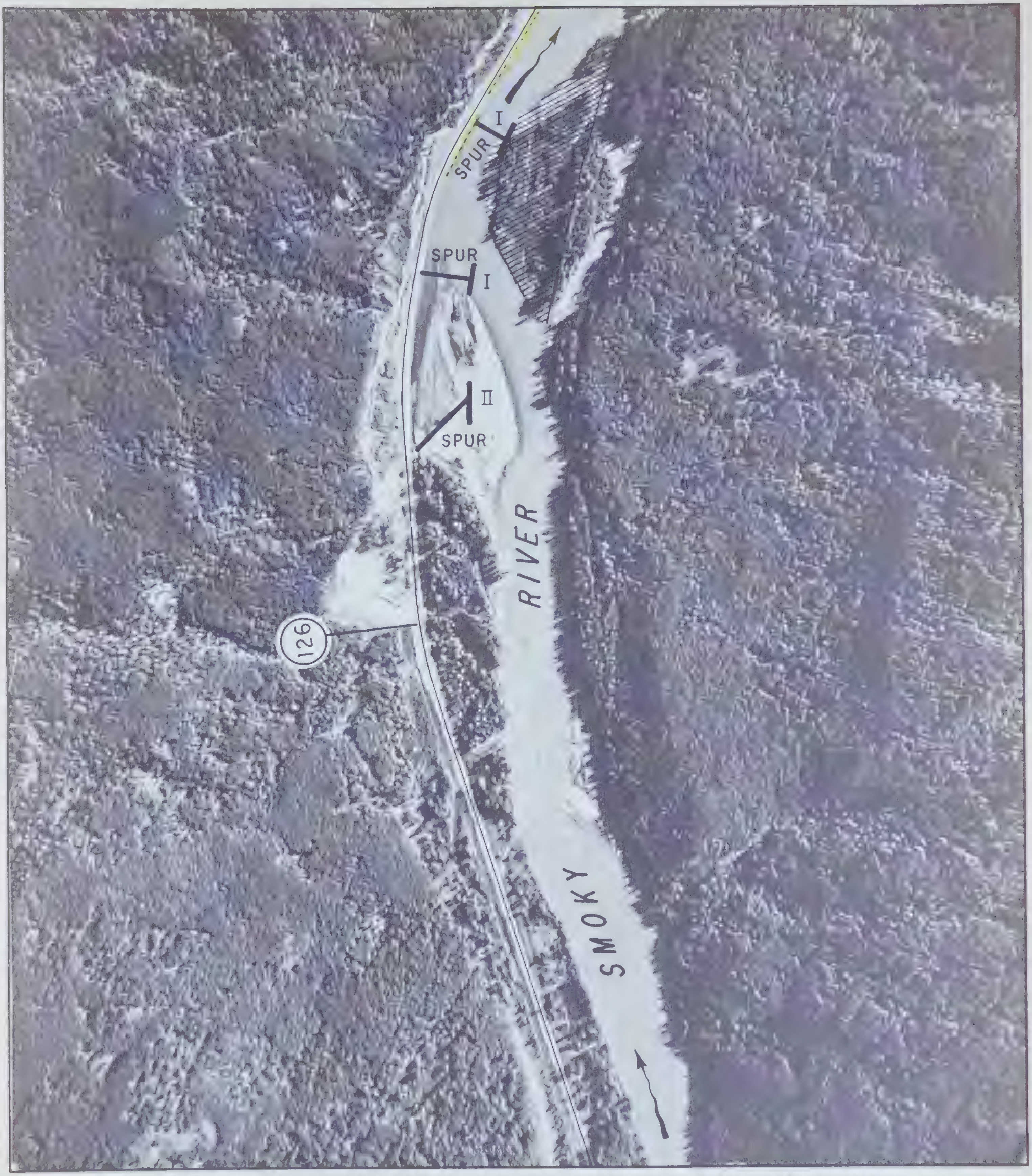
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

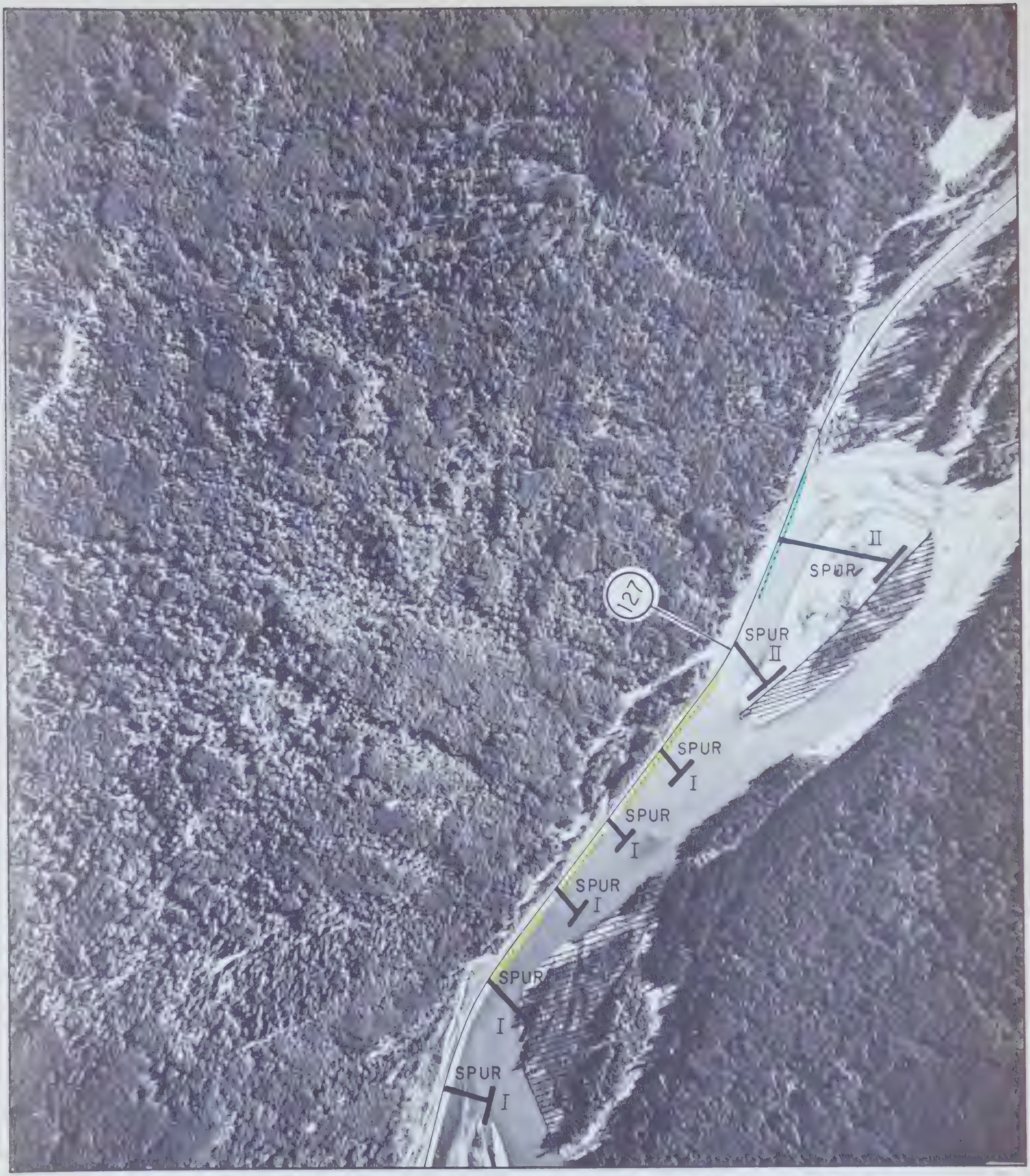
PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 300' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

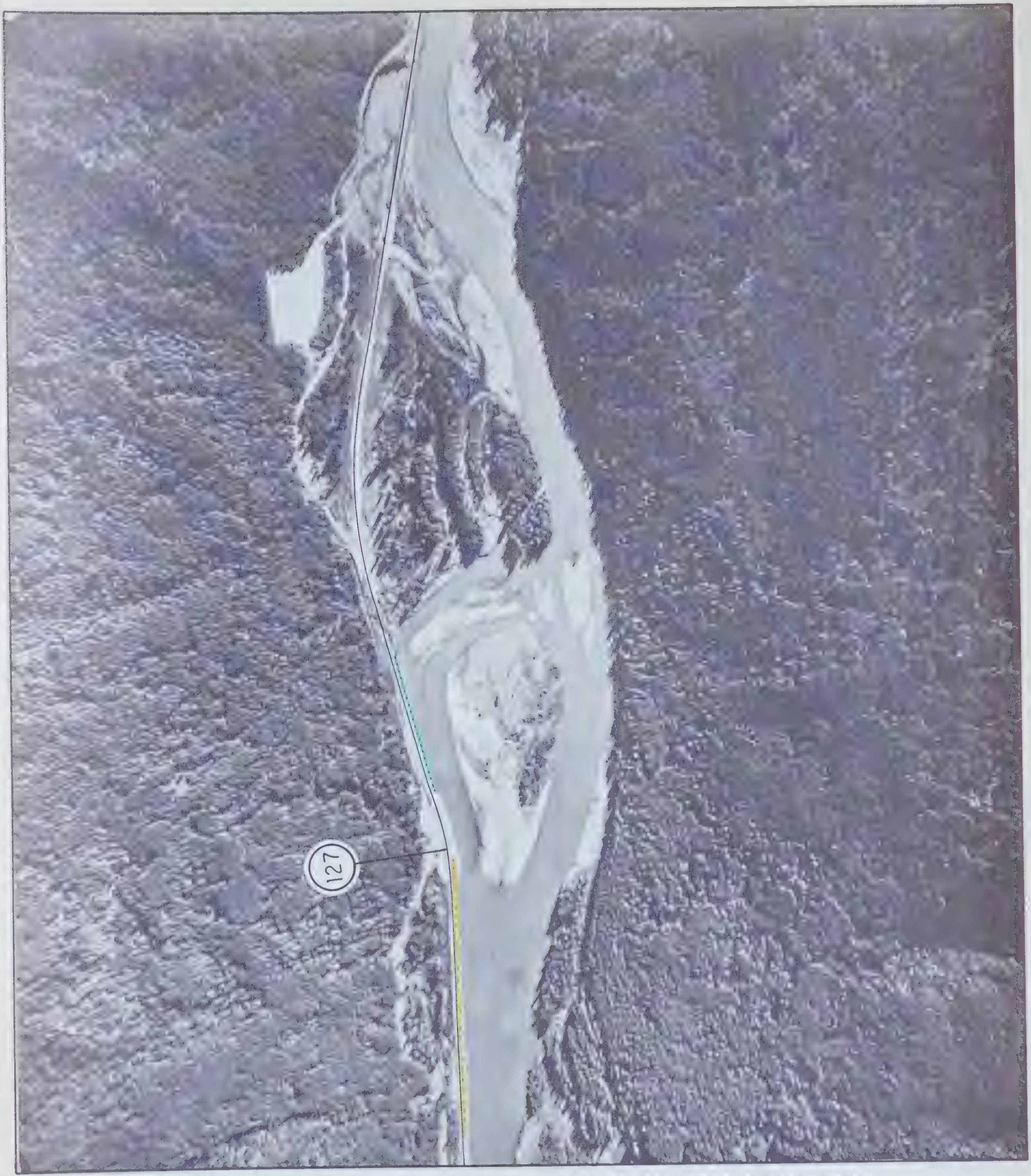
PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)

NOTE- SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE
CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.



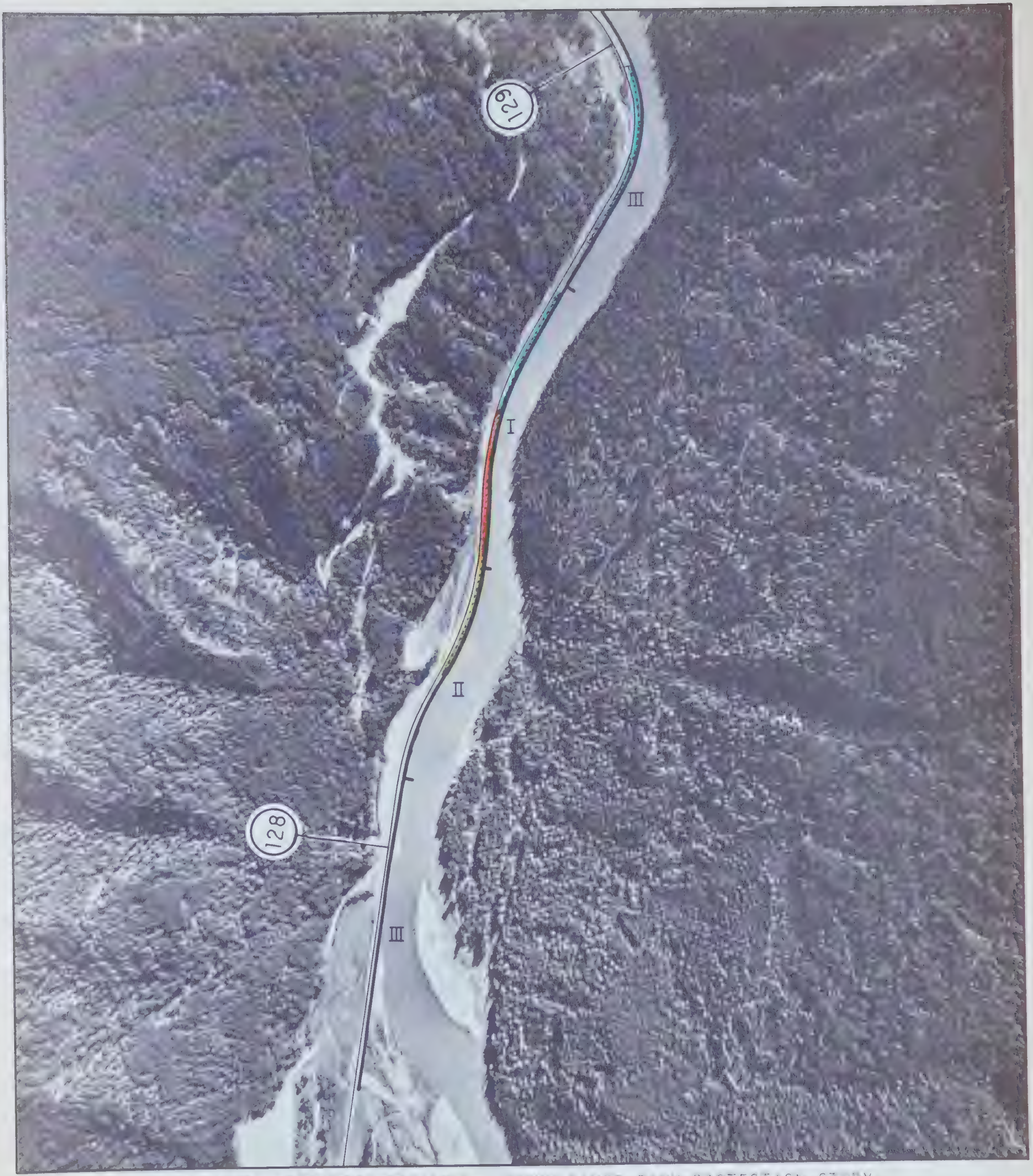
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 500' (APPROX.)



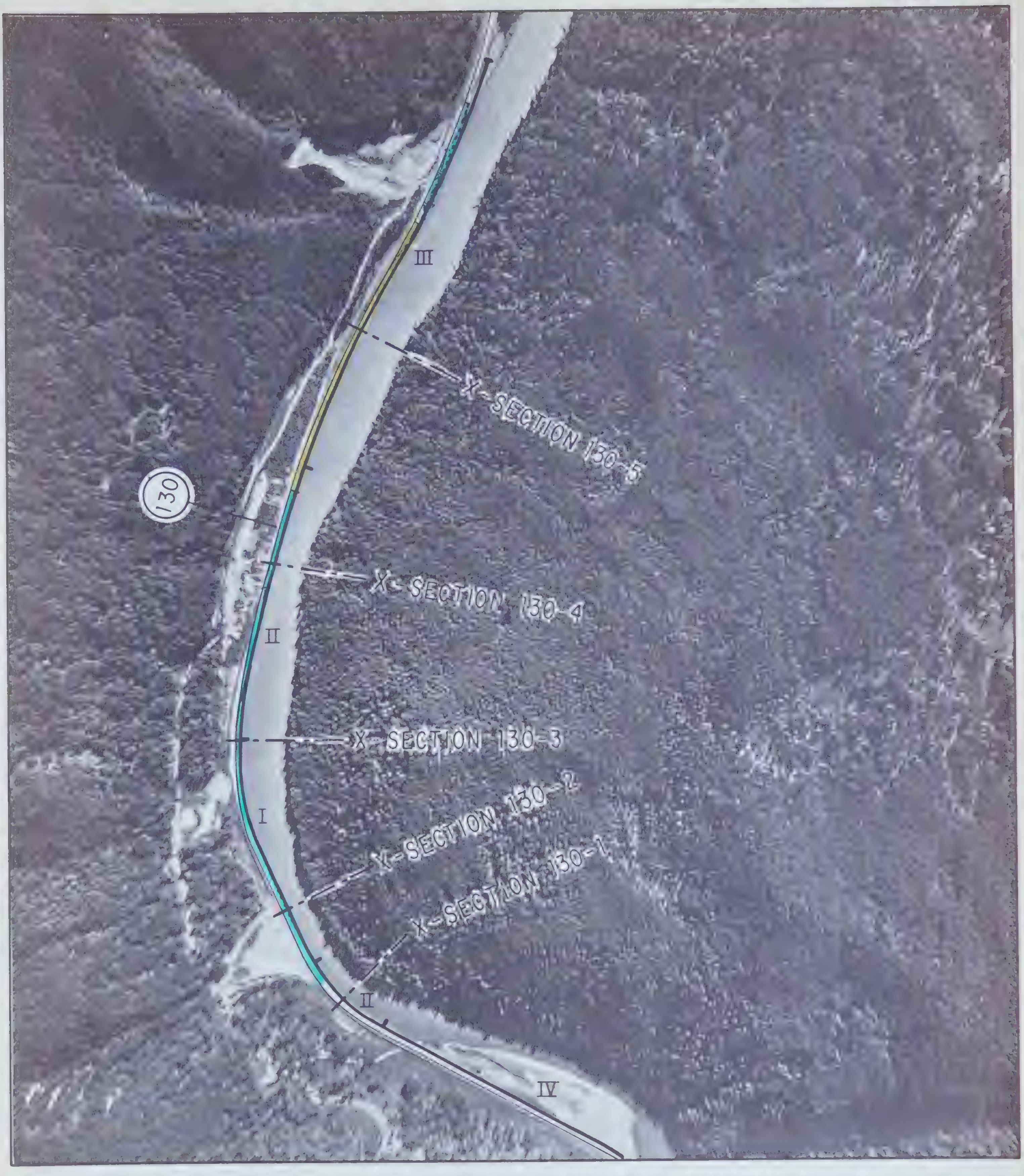
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 1000' (APPROX.)



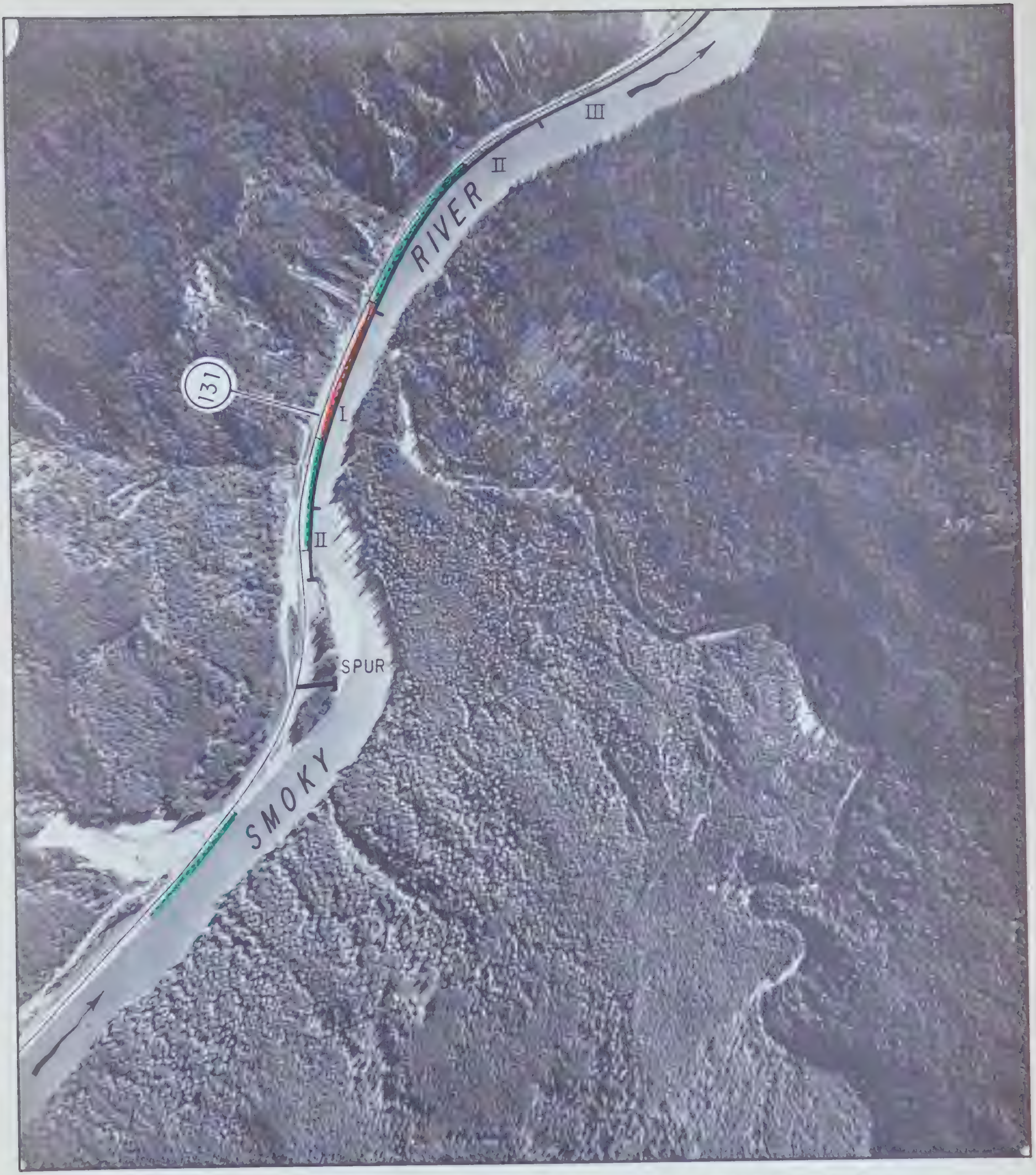
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

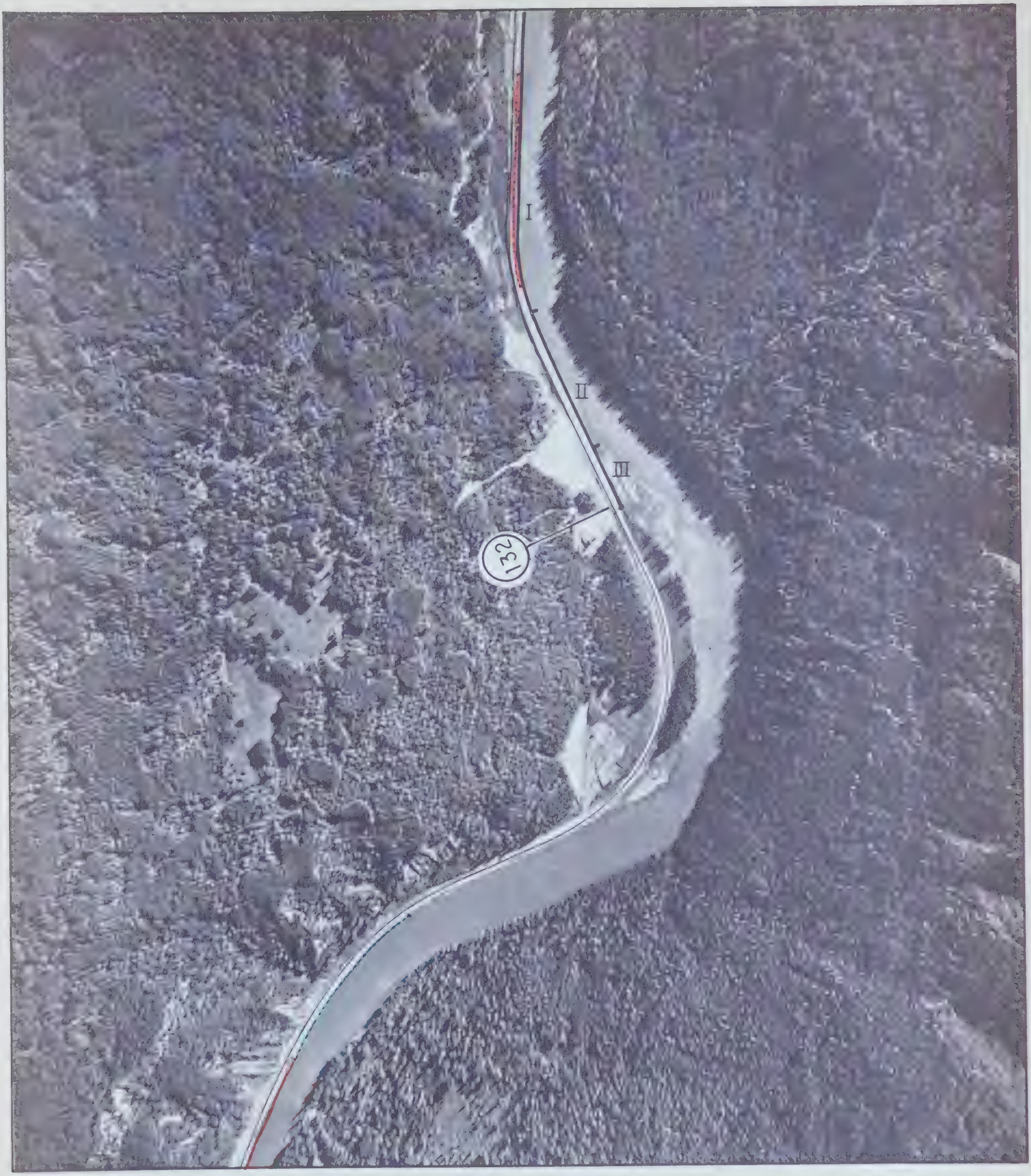
PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 200' (APPROX.)
NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972)    DISCHARGE ABOUT 2000 C.F.S.



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

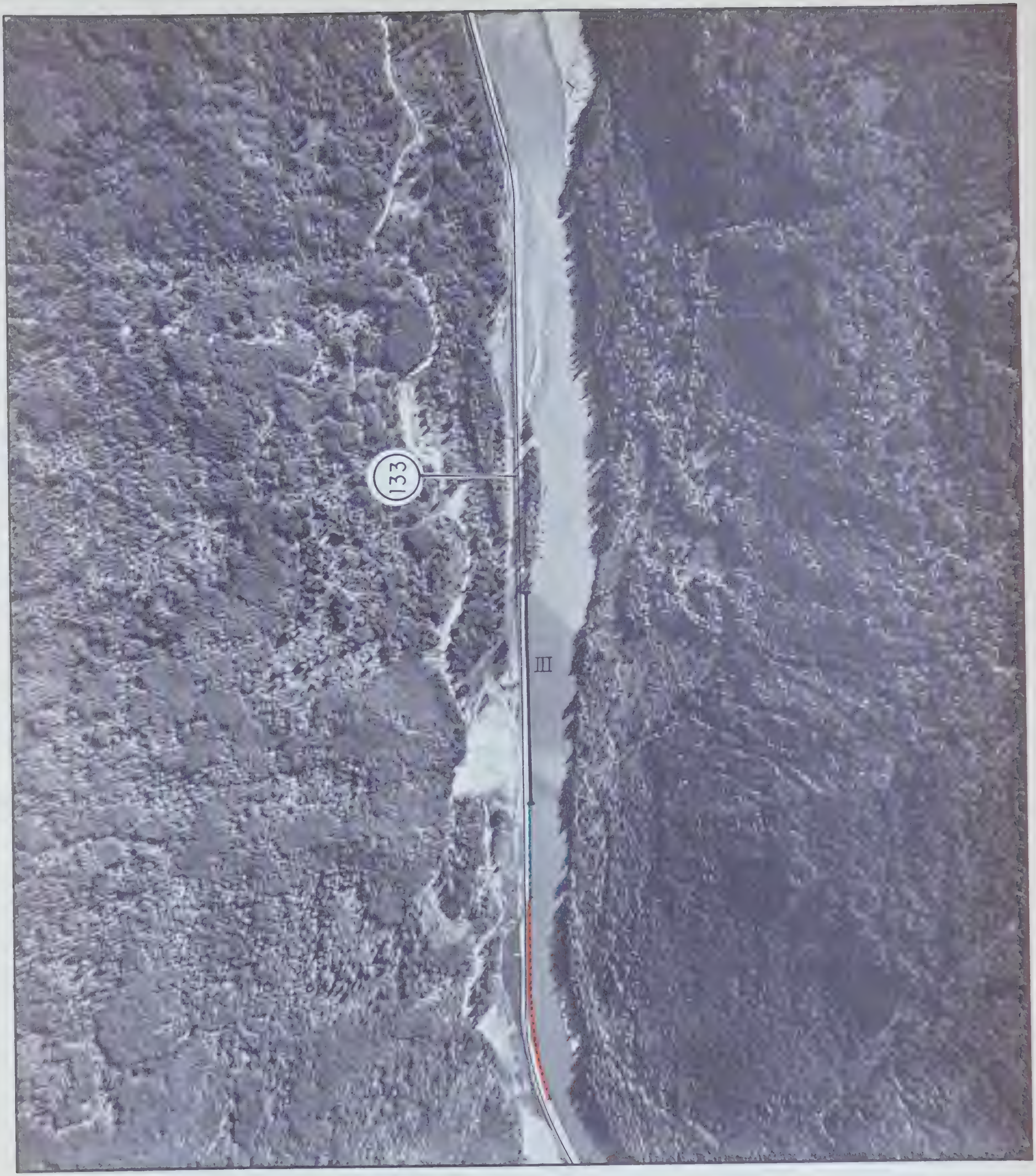
PHOTOGRAPHY TAKEN JULY 1972   SCALE 1" = 600' (APPROX.)

NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE. CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.



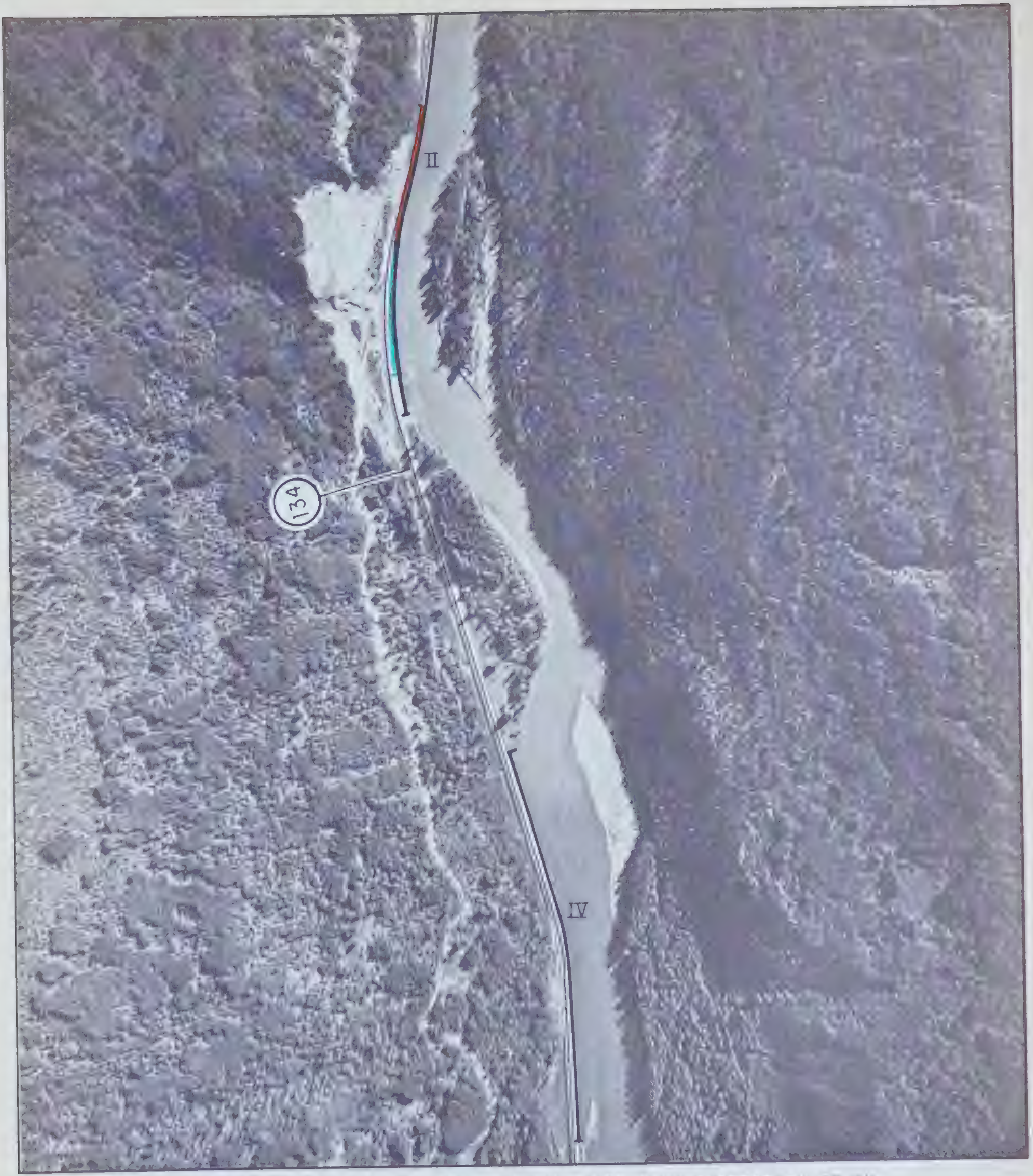
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 300' (APPROX.)



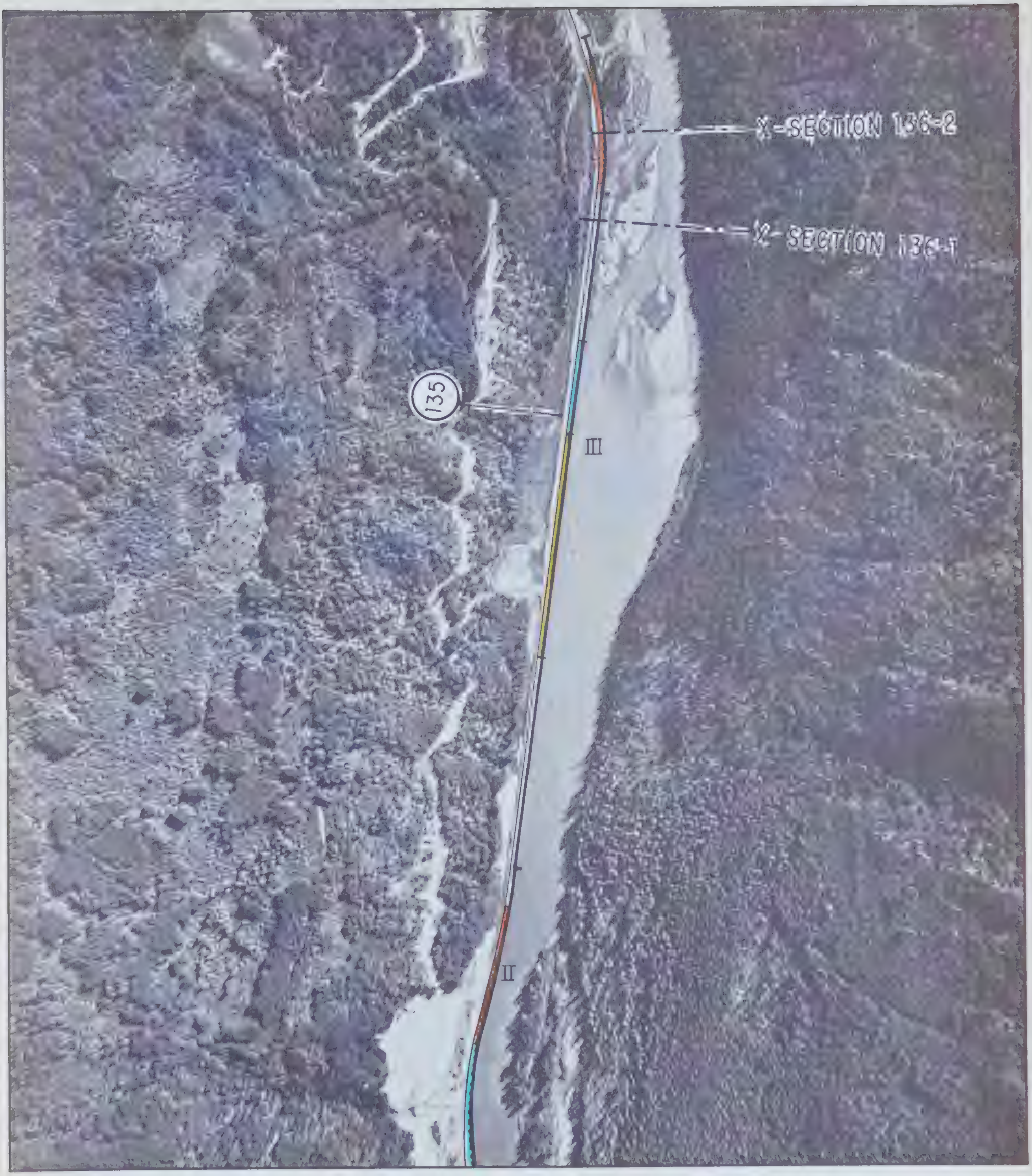
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)



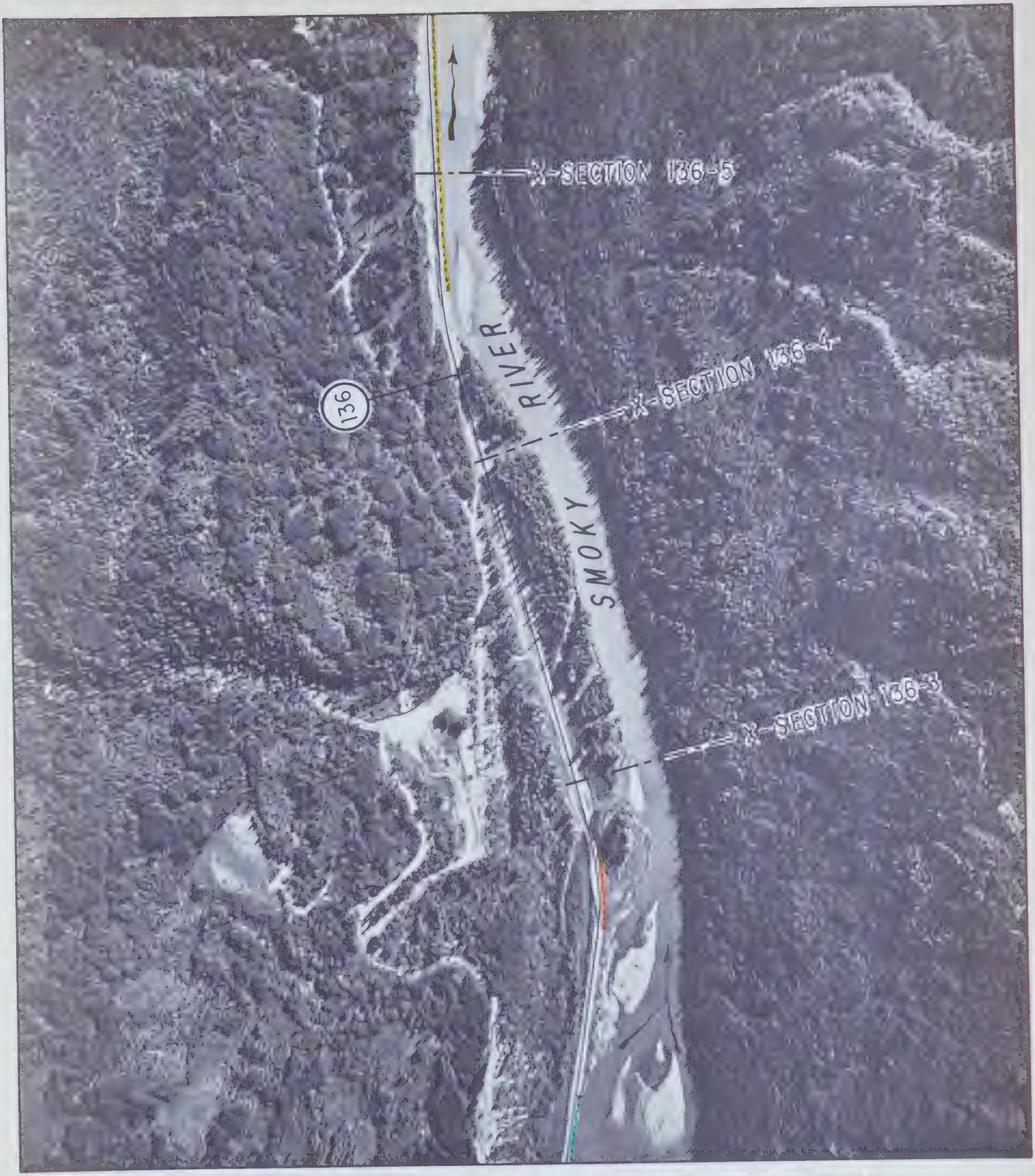
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)
NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972)    DISCHARGE ABOUT 2000 C.F.S.

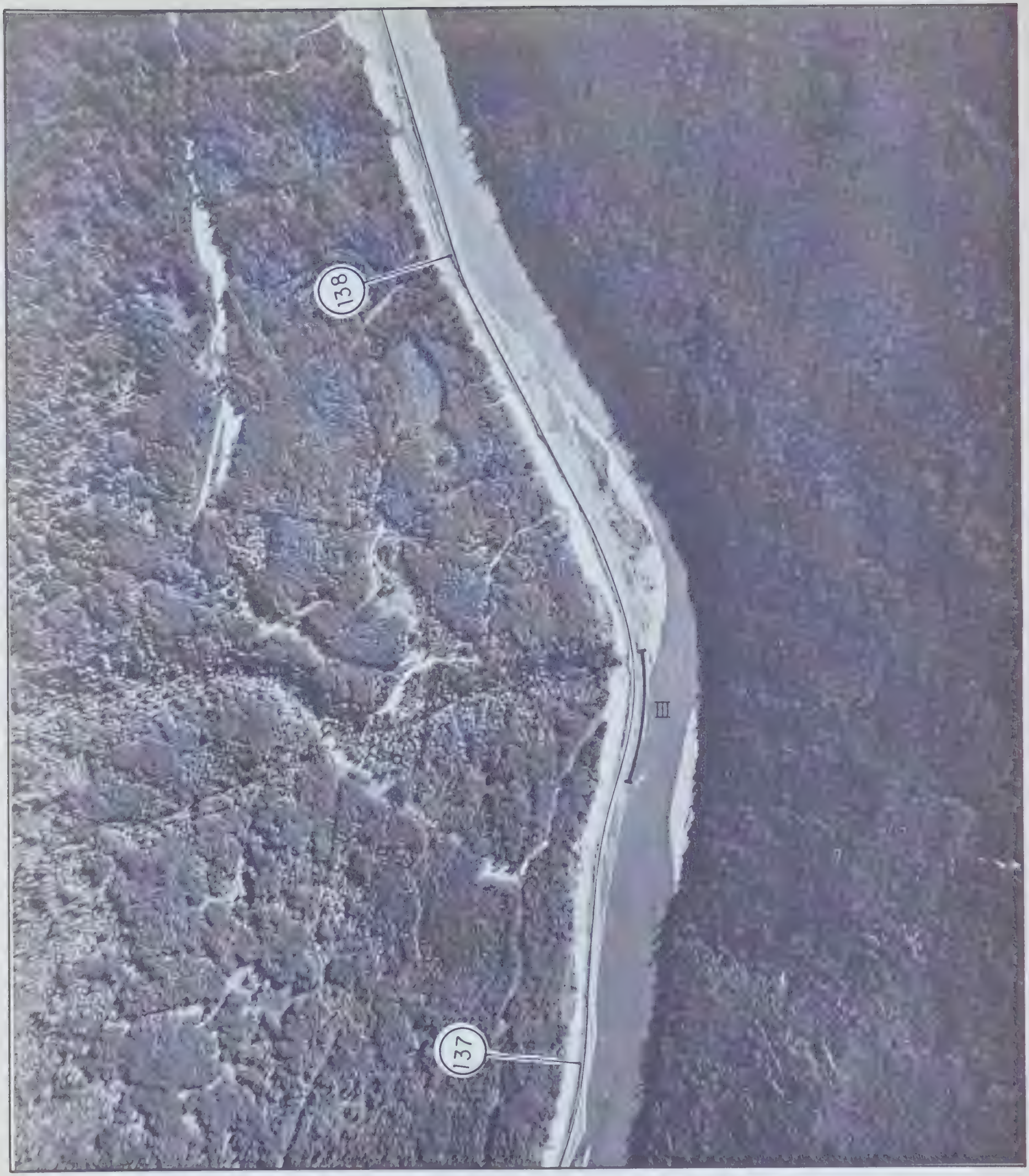


ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)

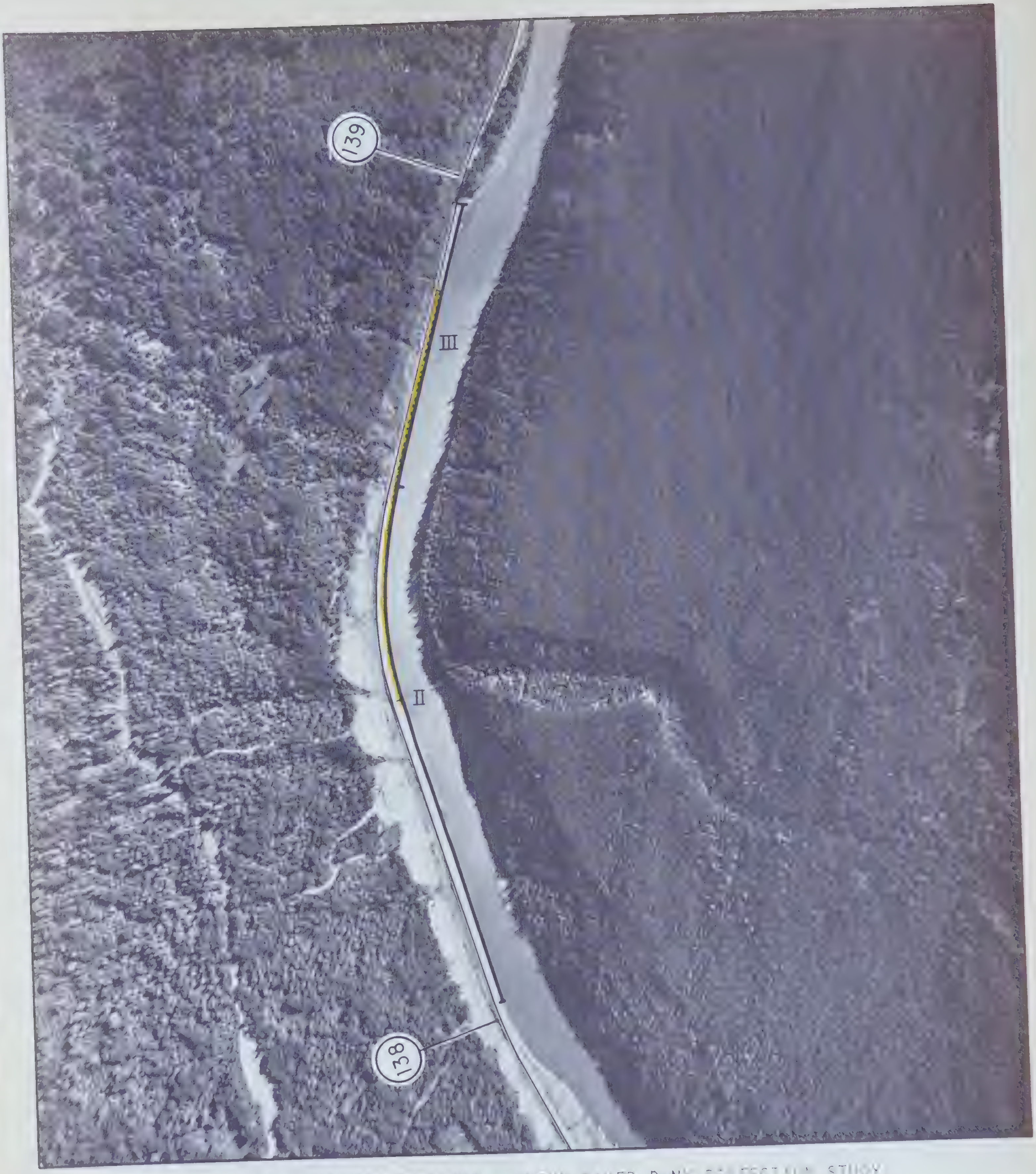
NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE
CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS

NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972)    DISCHARGE ABOUT 2000 C.F.S.



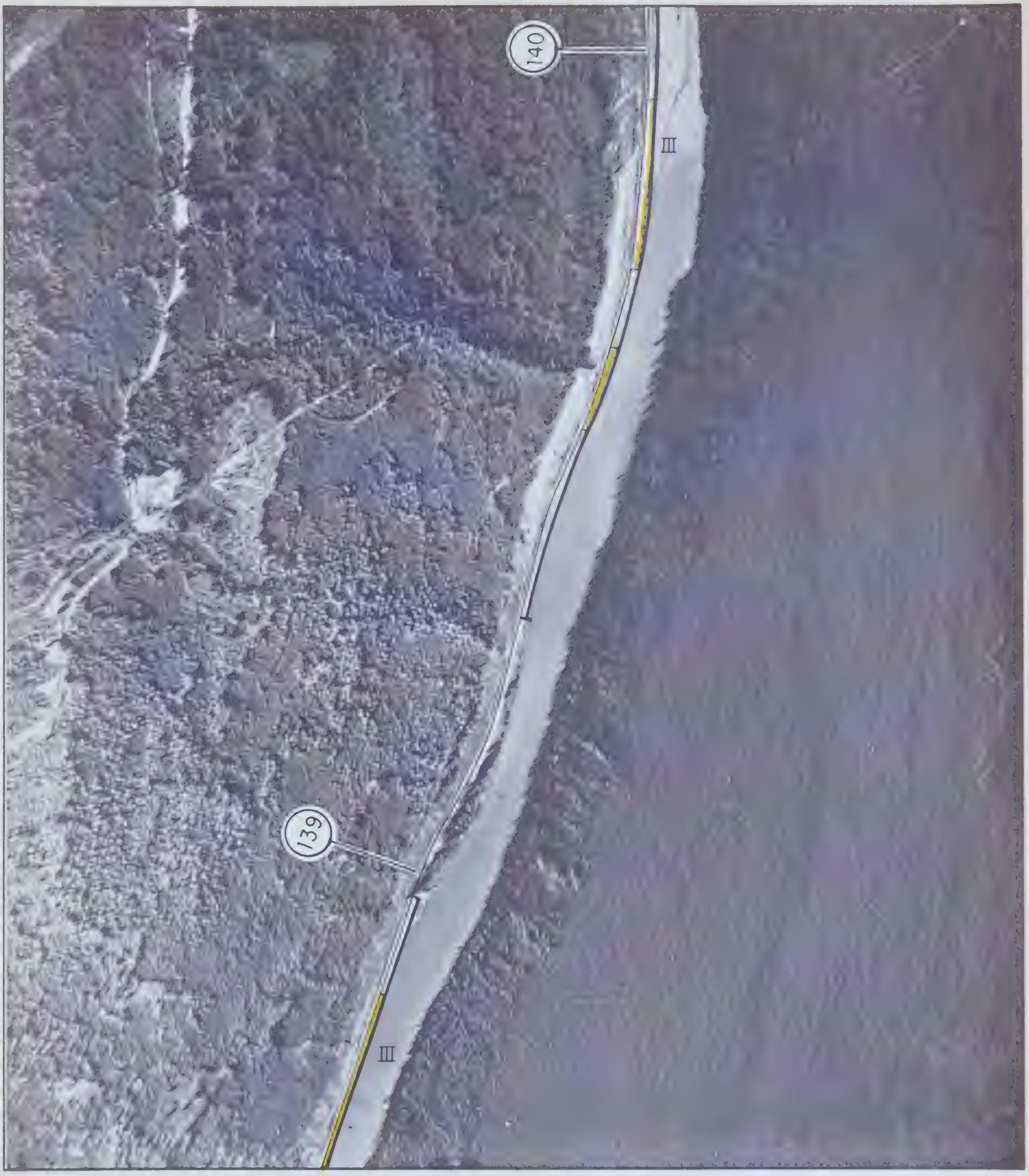
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972   SCALE 1" = 500' (APPROX.)



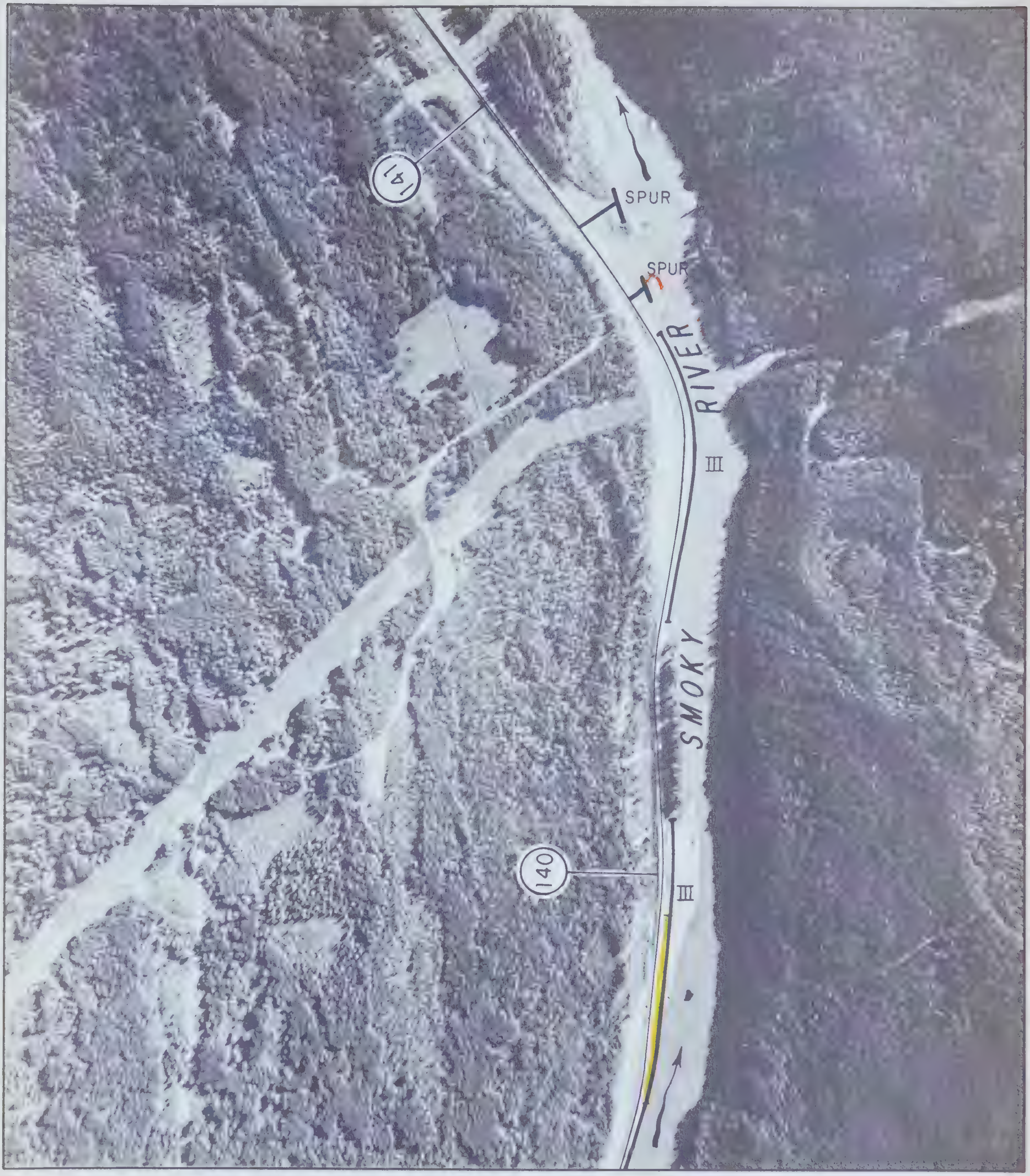
ALBERTA RESOURCES RAILWAY   SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972   SCALE 1" = 500' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

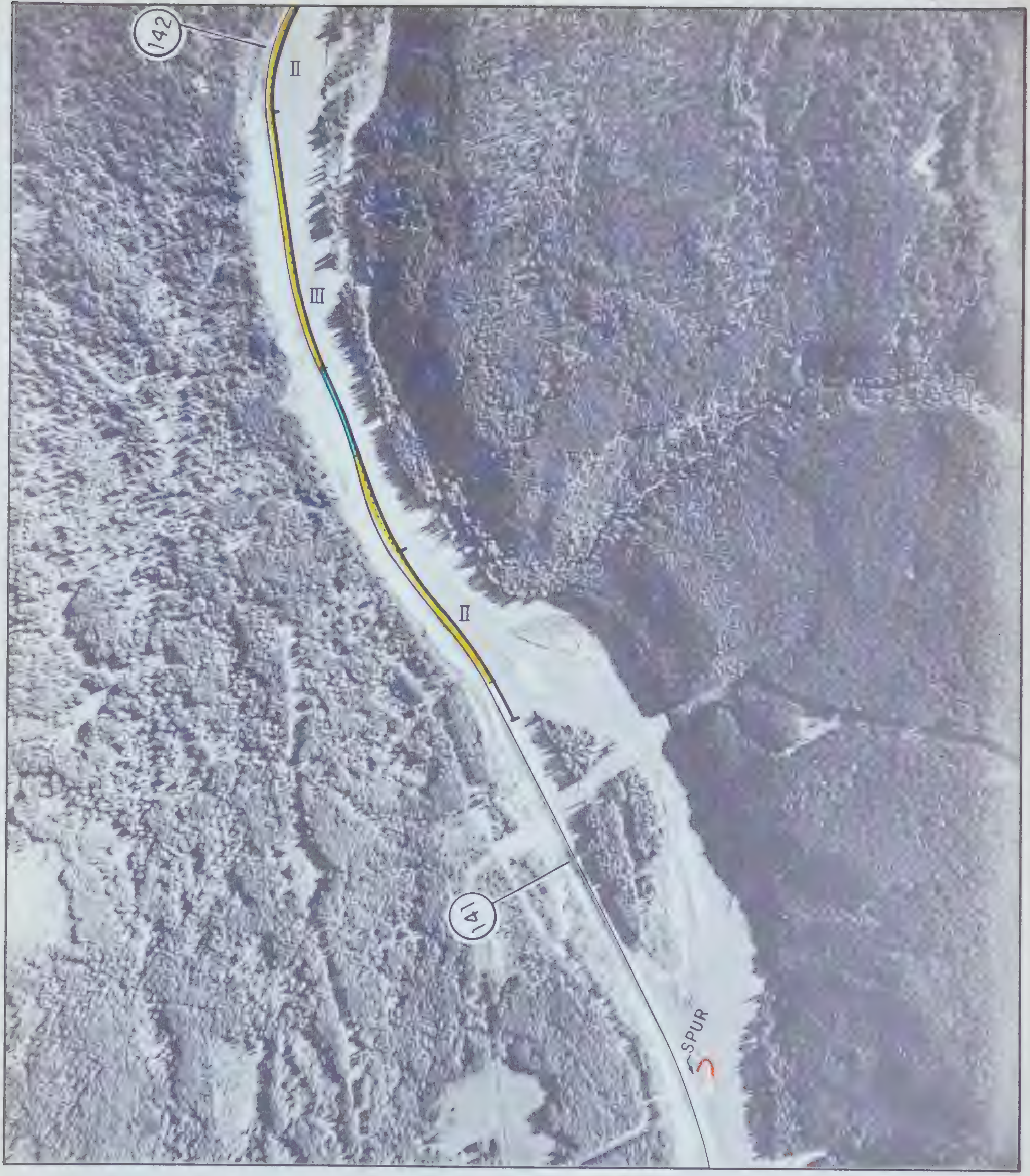
PHOTOGRAPHY TAKEN JULY 1972   SCALE 1" = 500' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

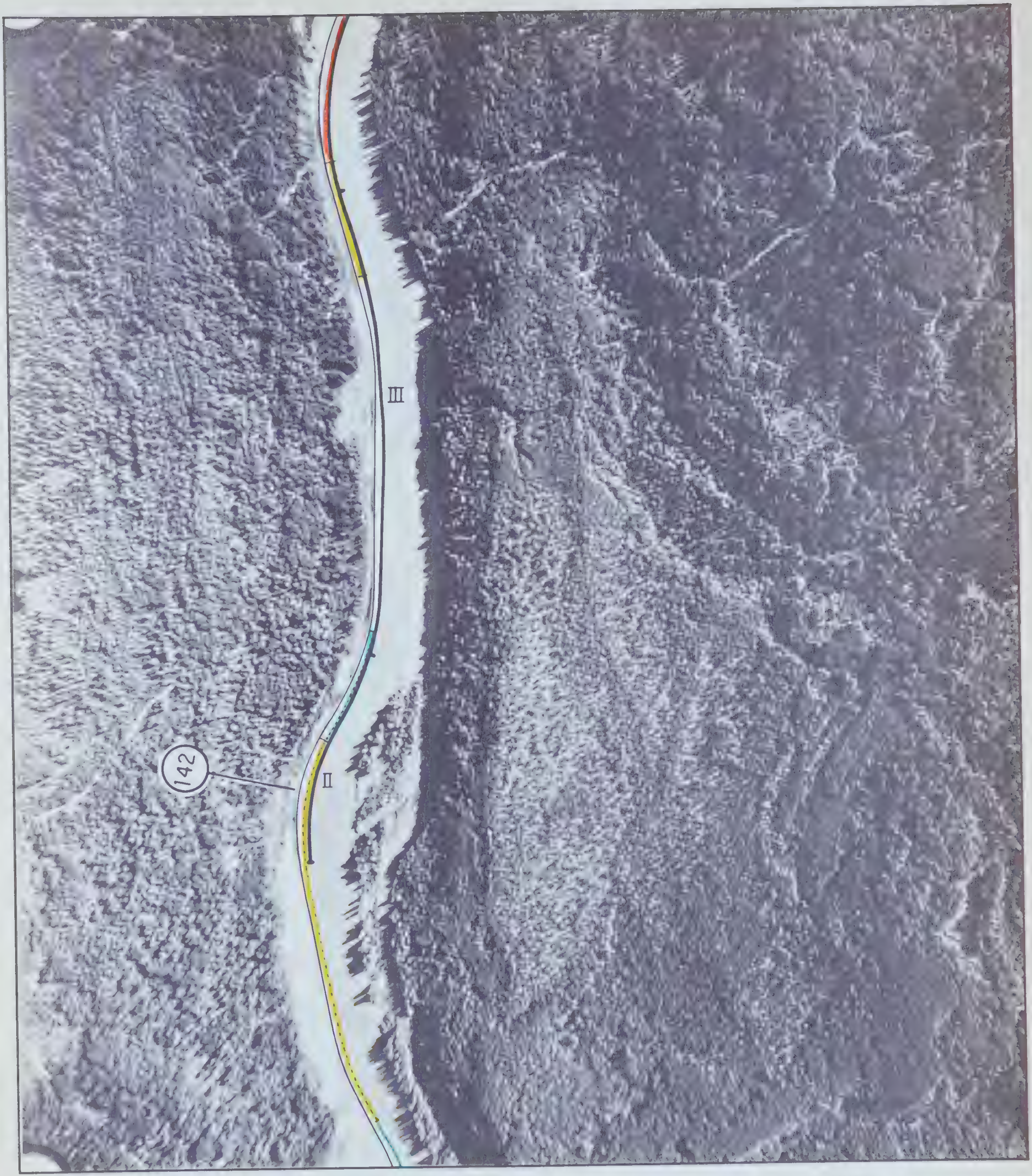
PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)

NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE. CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.



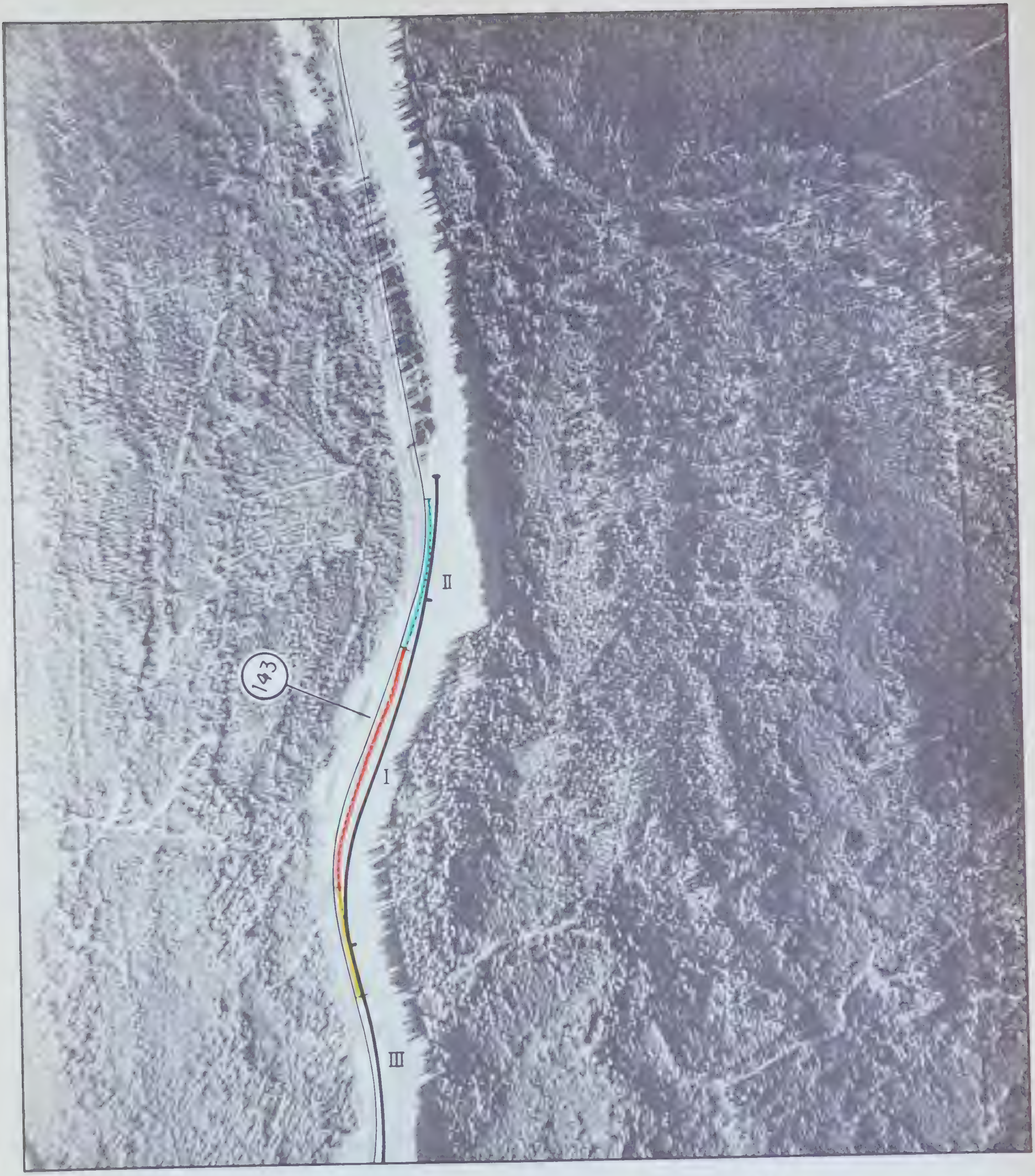
ALBERTA RESOURCES RAILWAY – SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 500' (APPROX.)



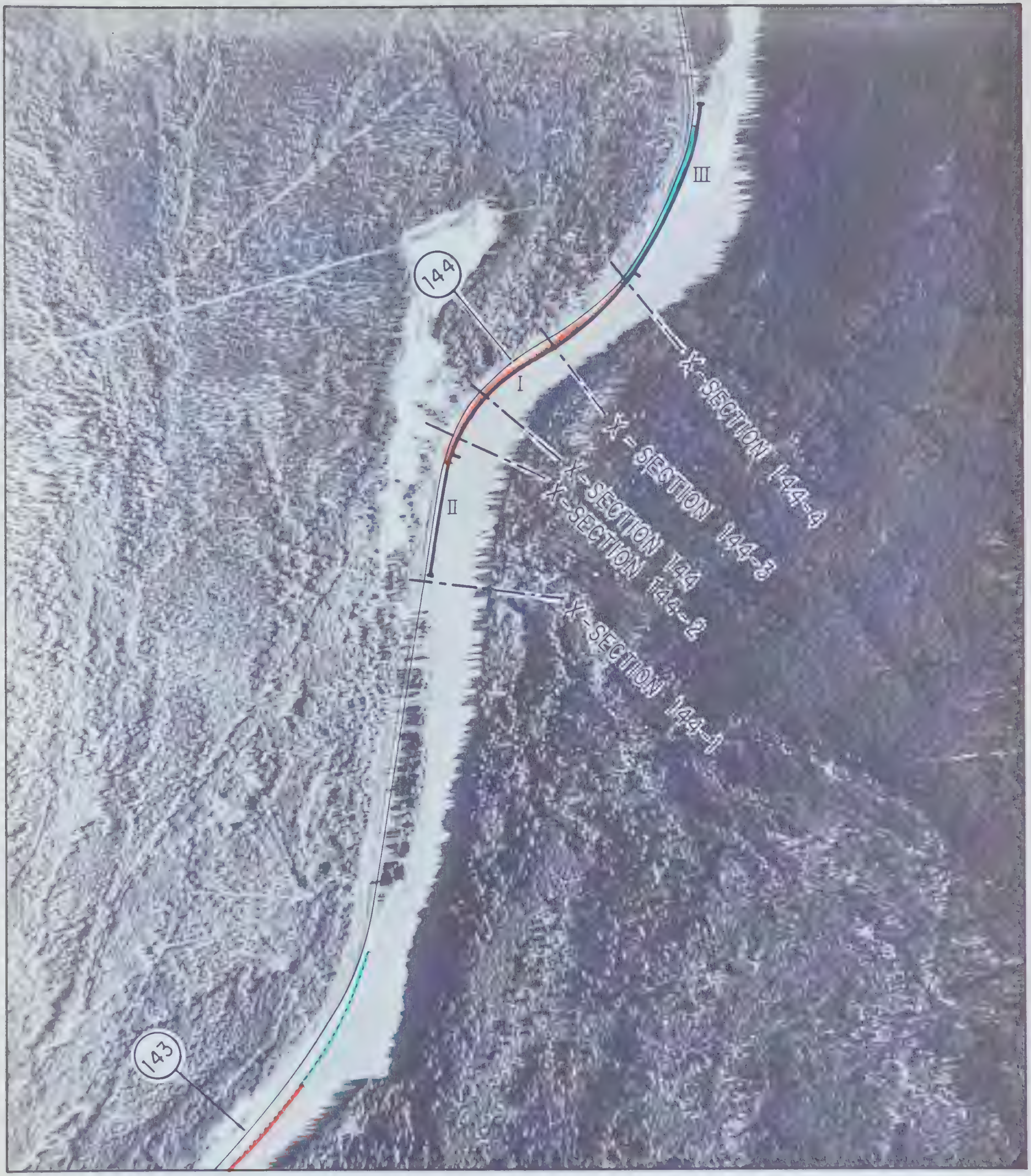
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

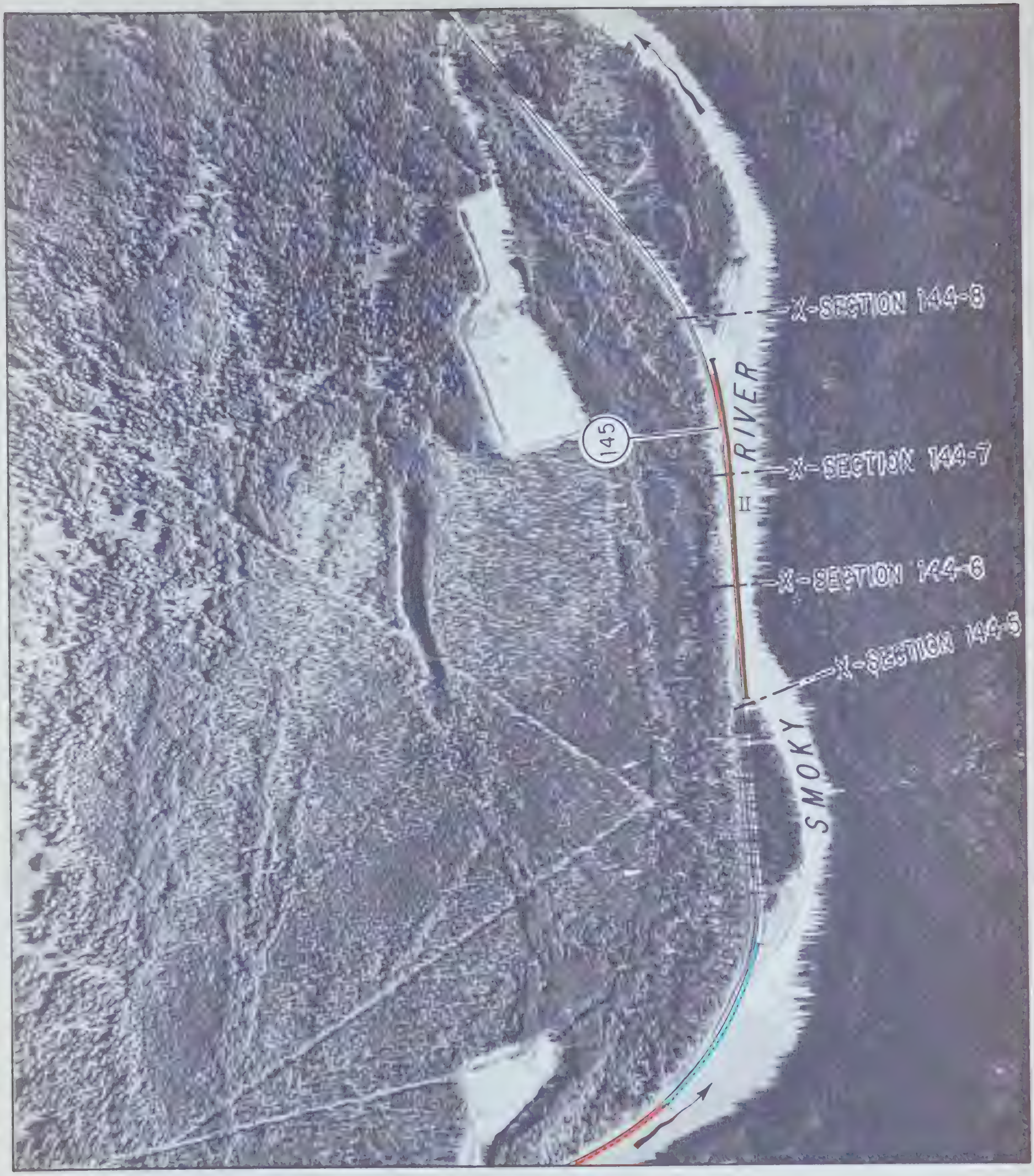
PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPH TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)

NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972) DISCHARGE ABOUT 2000 C.F.S.

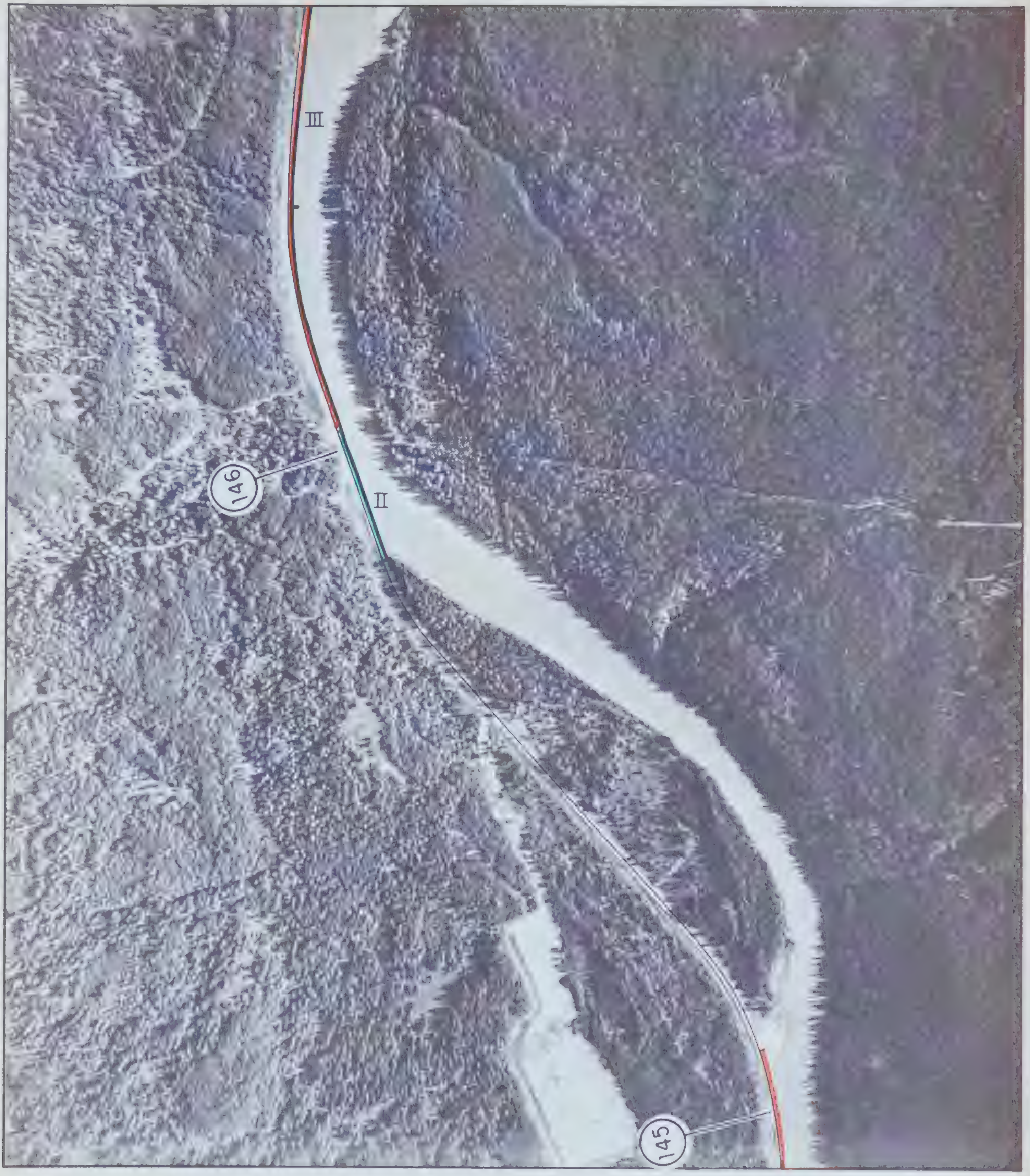


ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)

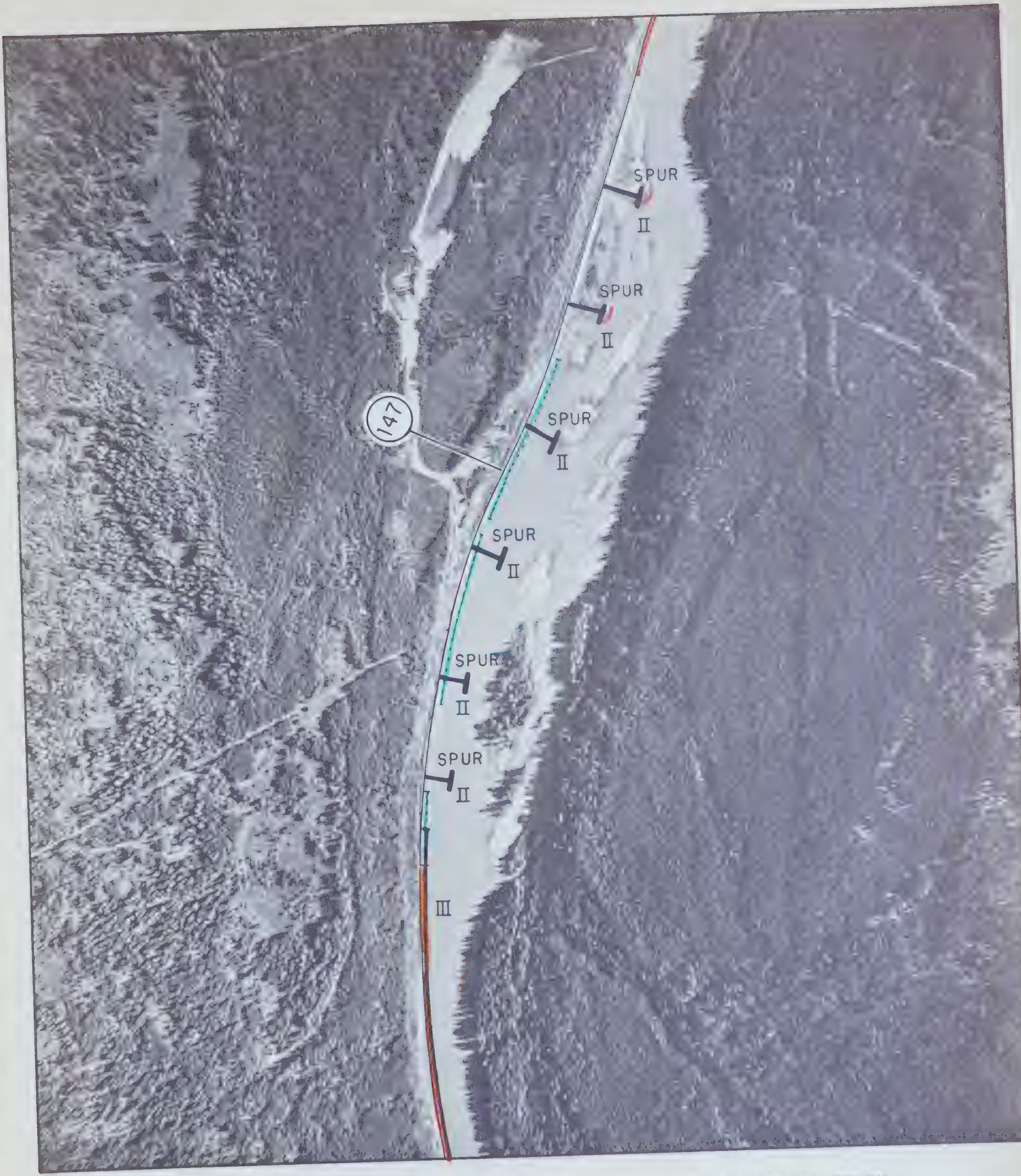
NOTE SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.

NOTE. SURVEYED X-SECTIONS (NOVEMBER 1972) DISCHARGE ABOUT 2000 C.F.S.



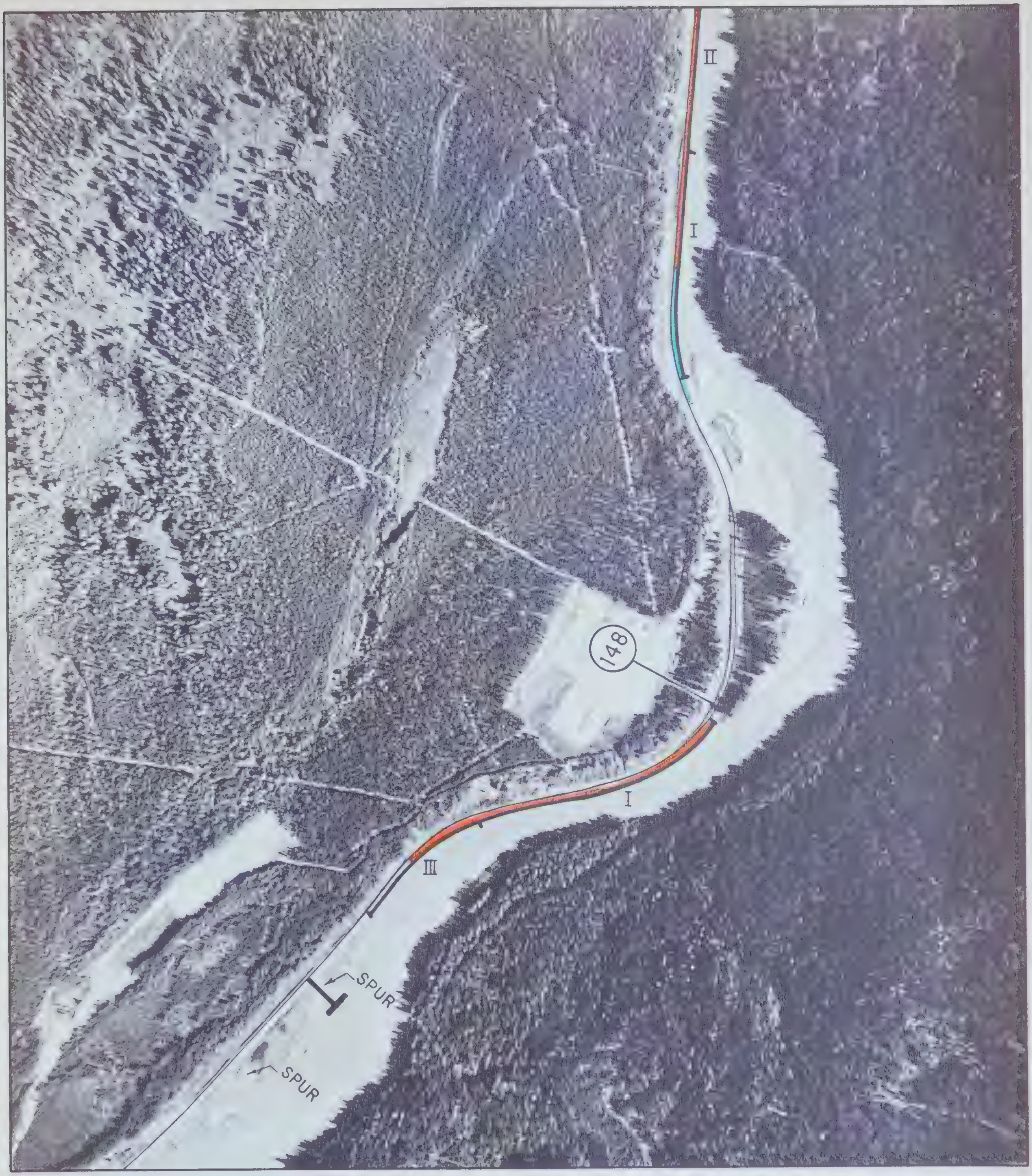
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)



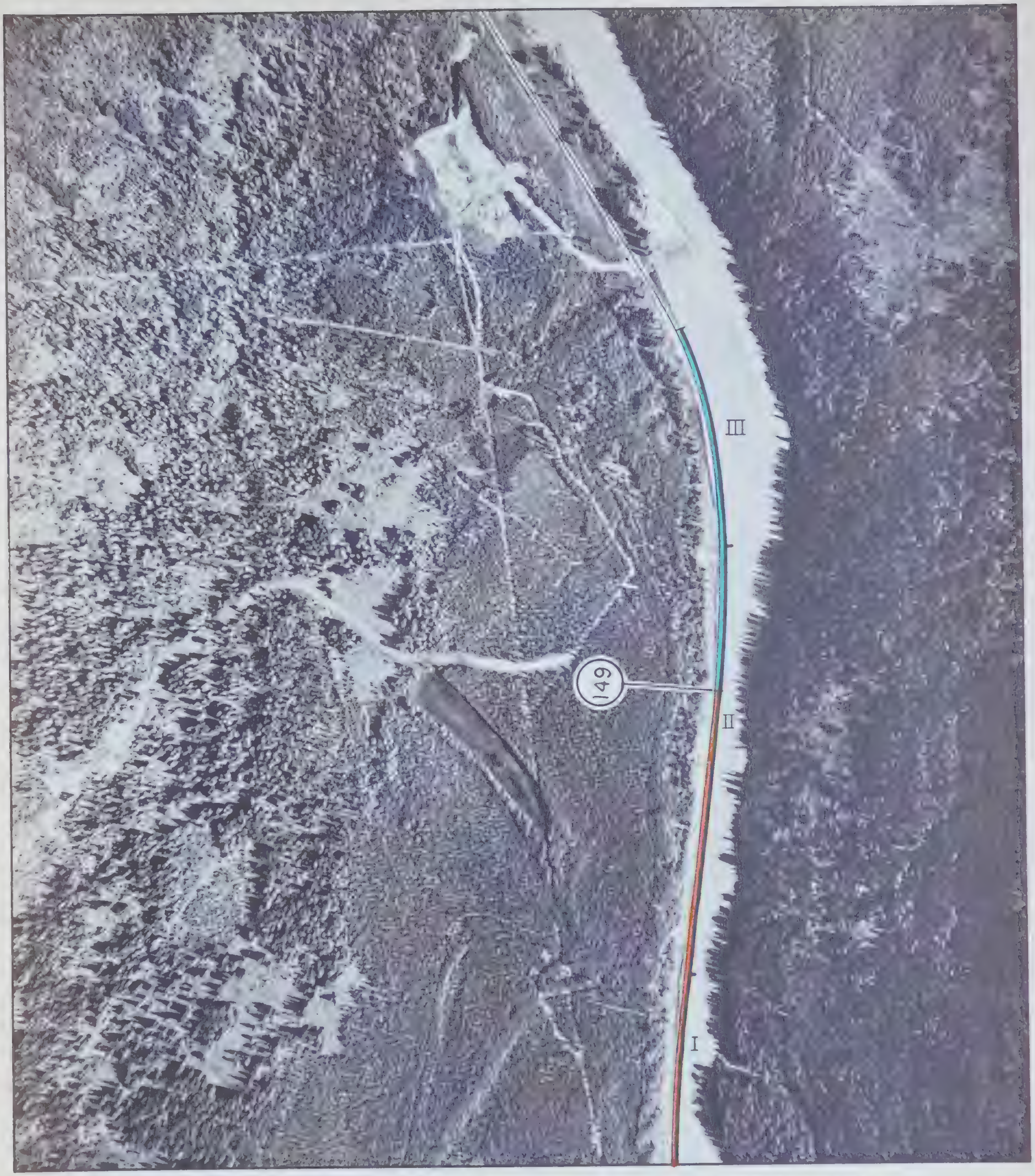
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972  SCALE 1" = 800' (APPROX.)



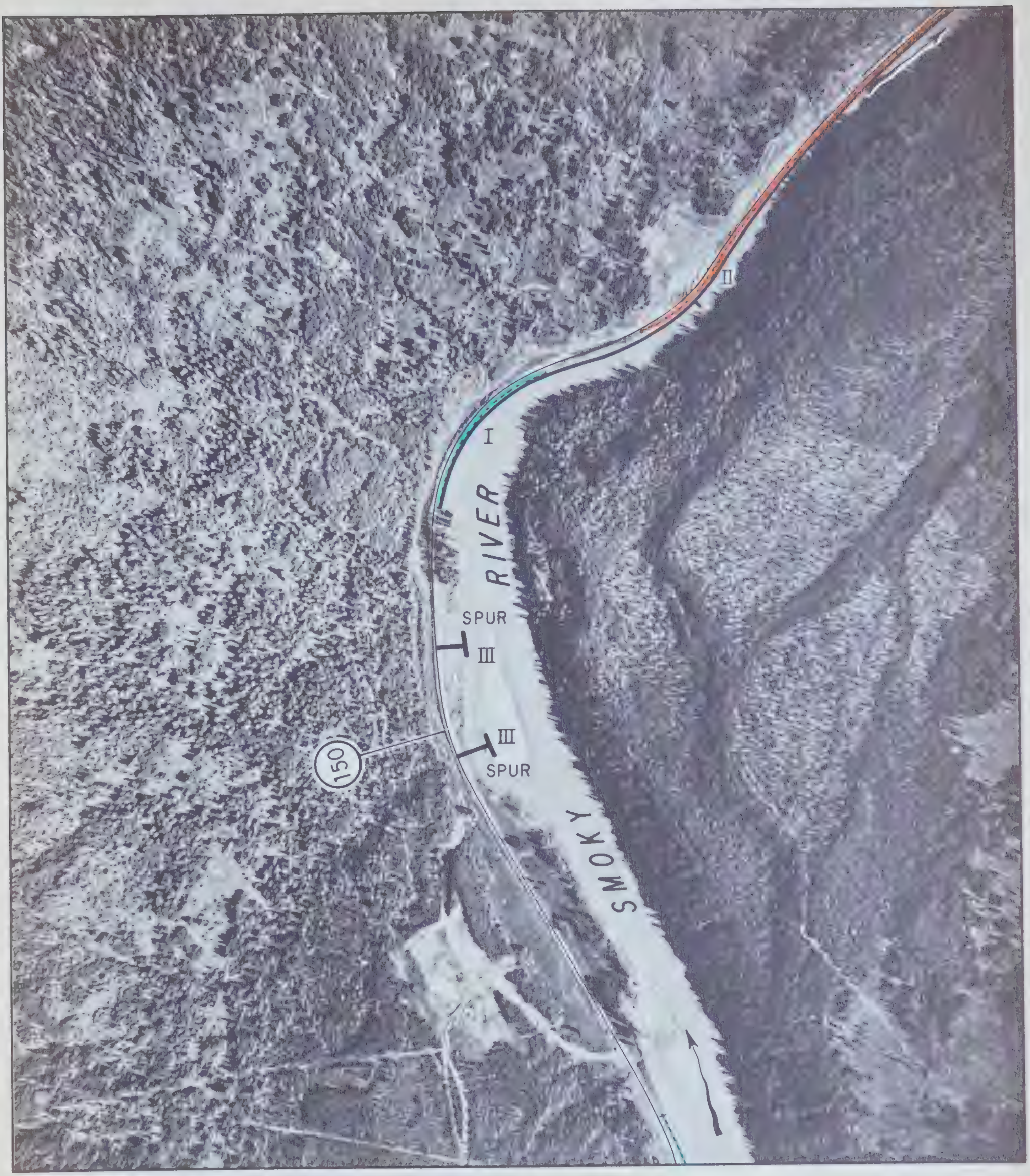
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 300' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

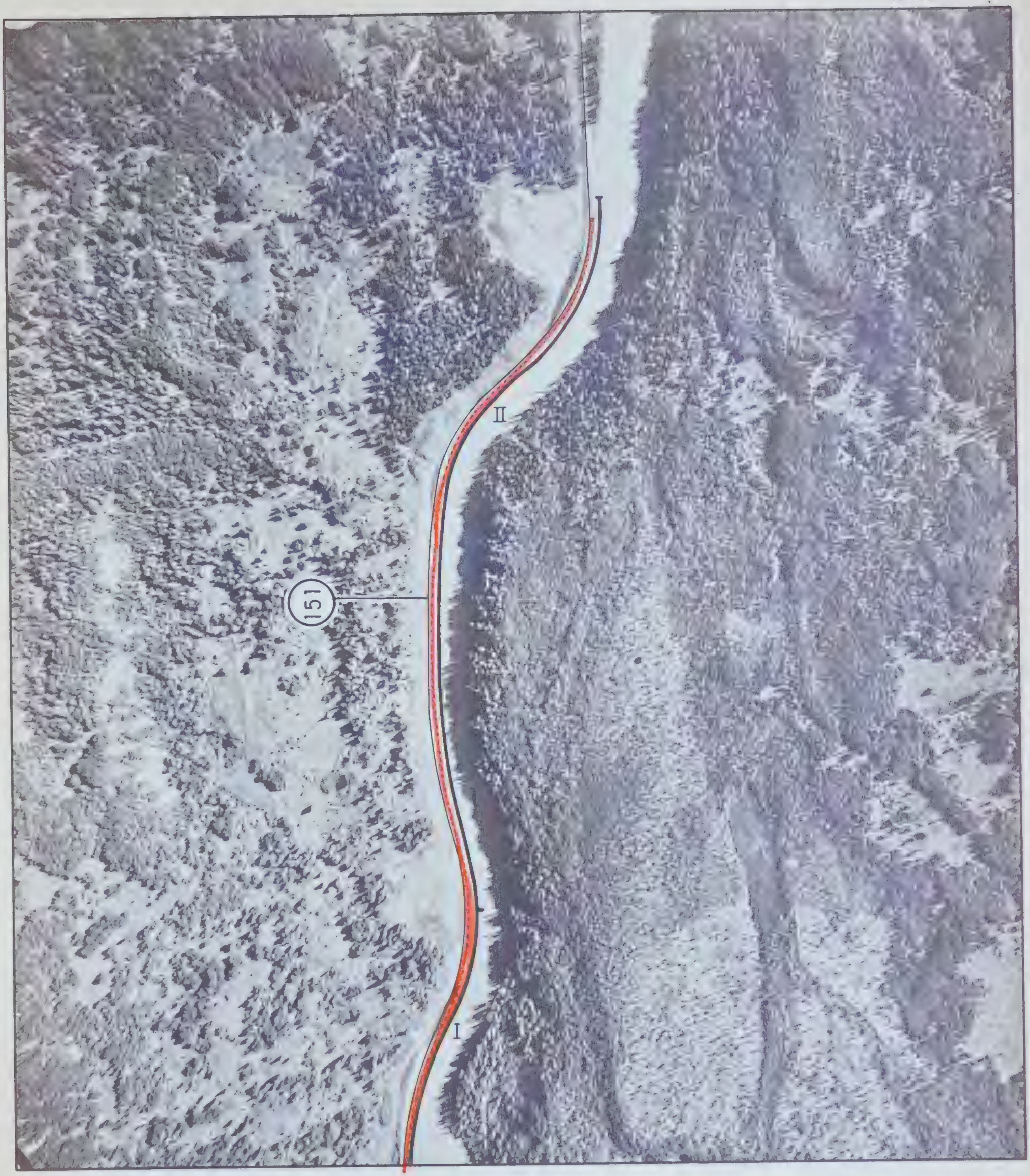
PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 300' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

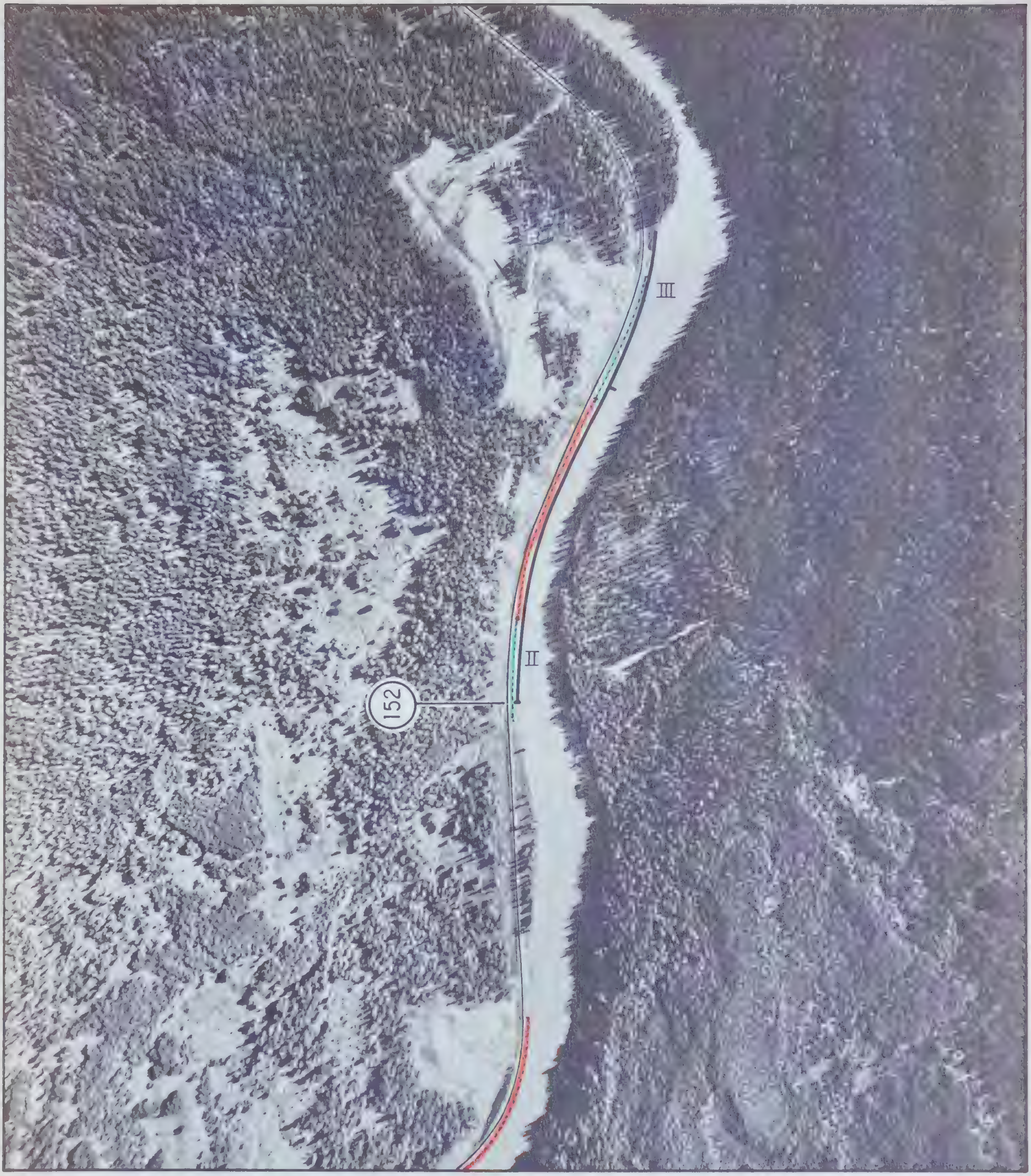
PHOTOGRAPHY TAKEN JULY 1972 SCALE 1'' = 800' (APPROX.)

NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.



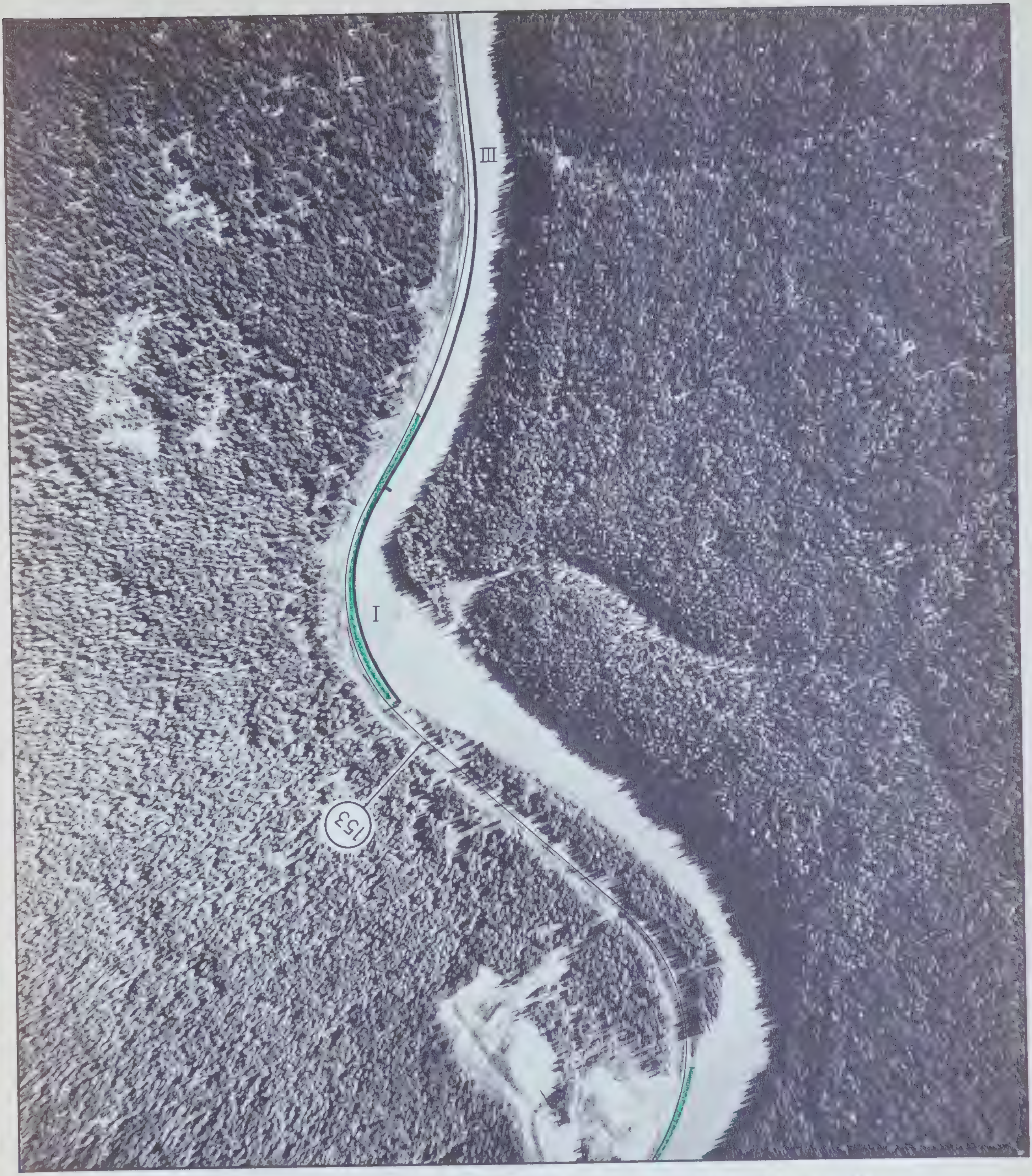
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 600' (APPROX.)



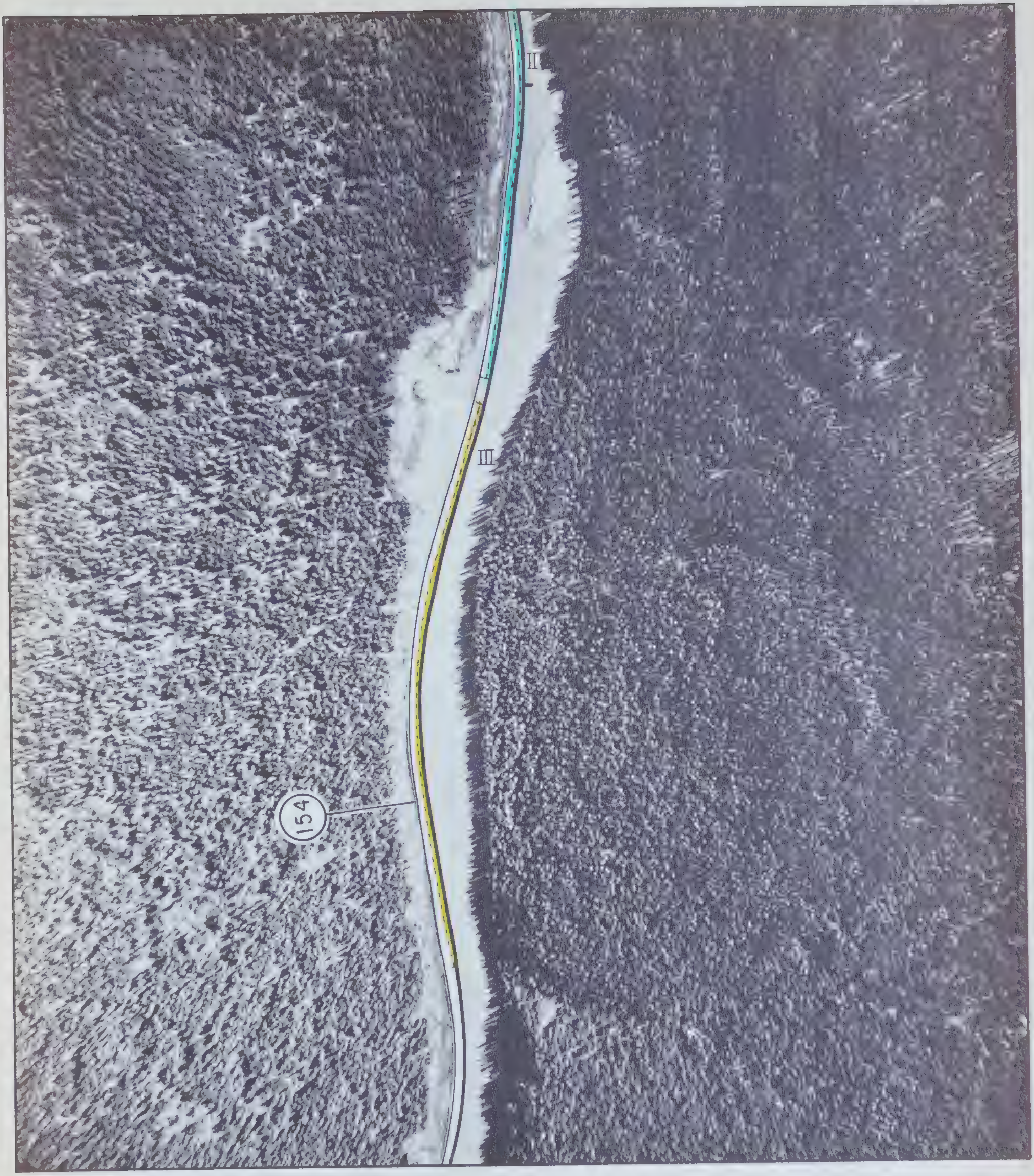
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)



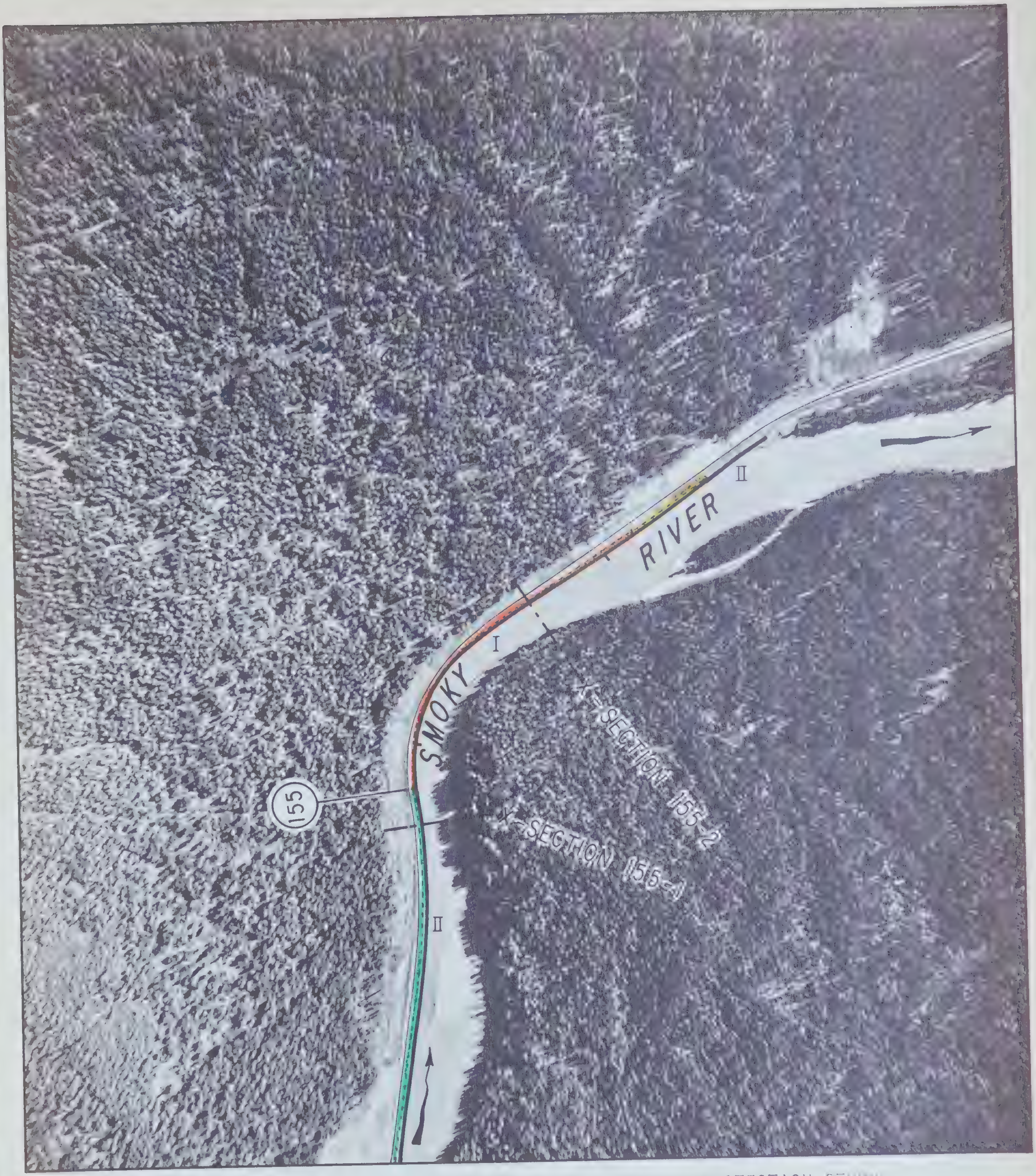
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = [illegible]' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 300' (APPROX.)

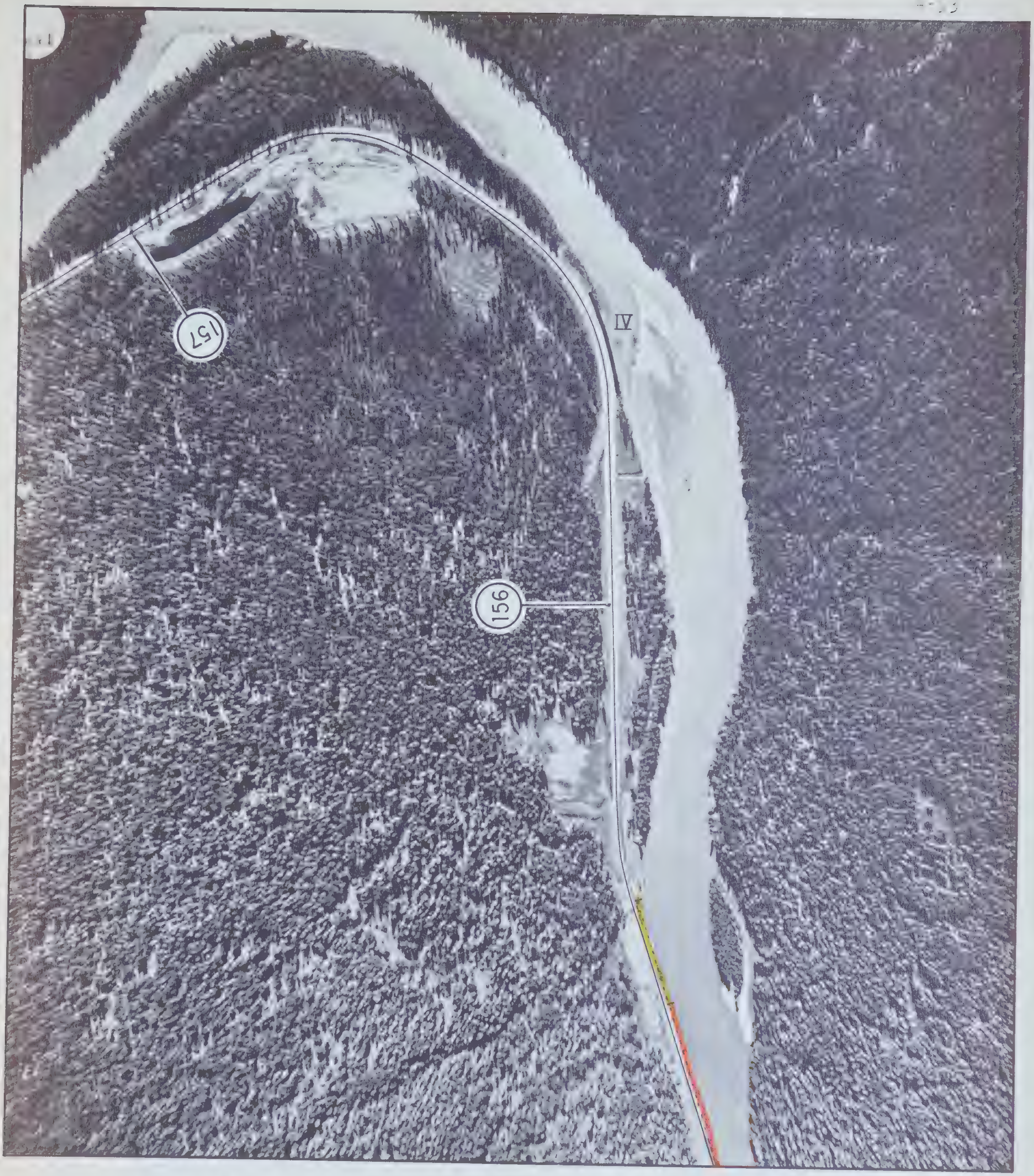


ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)

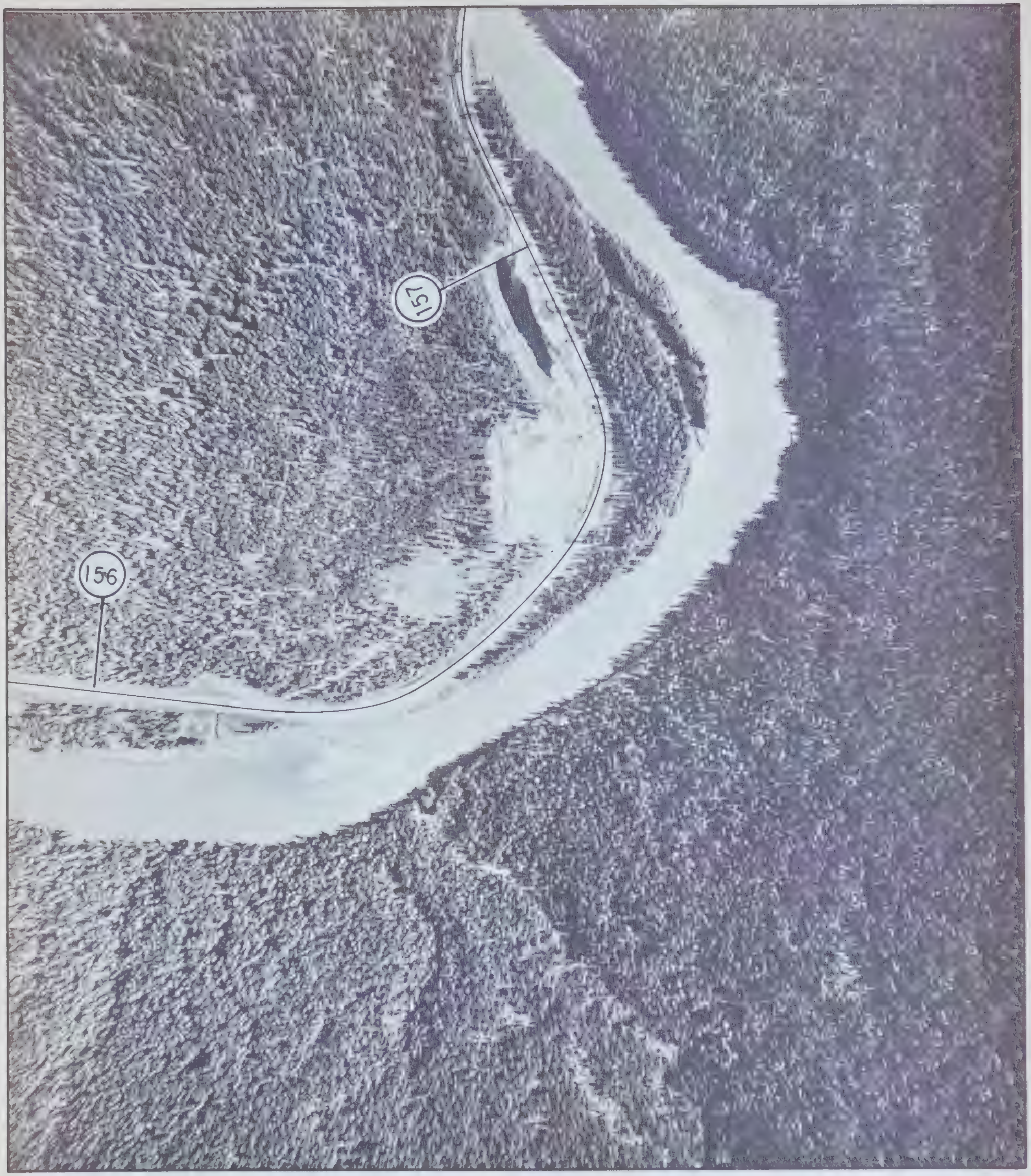
NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE. CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.

NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972) DISCHARGE ABOUT 2000 C.F.S.



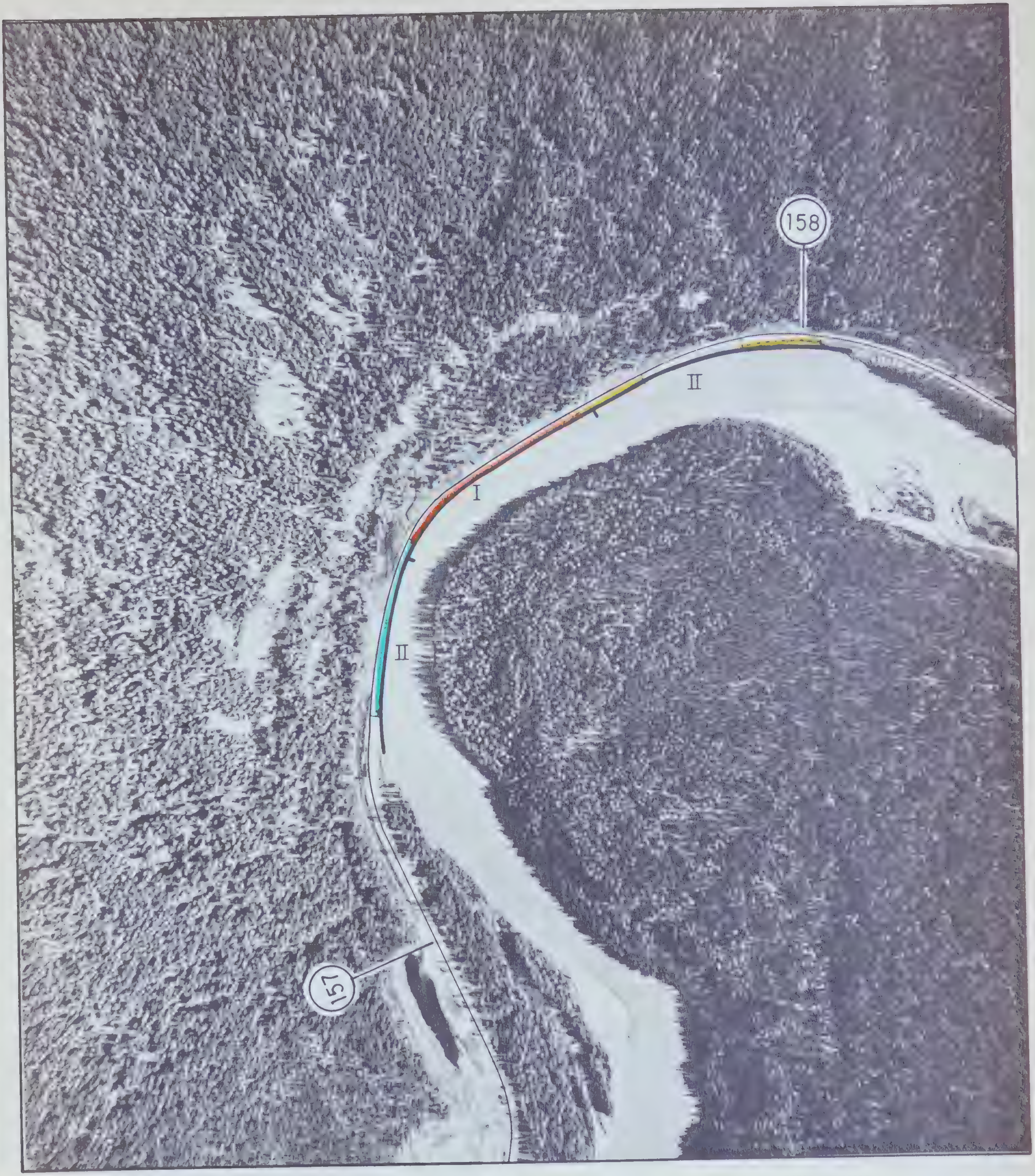
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)



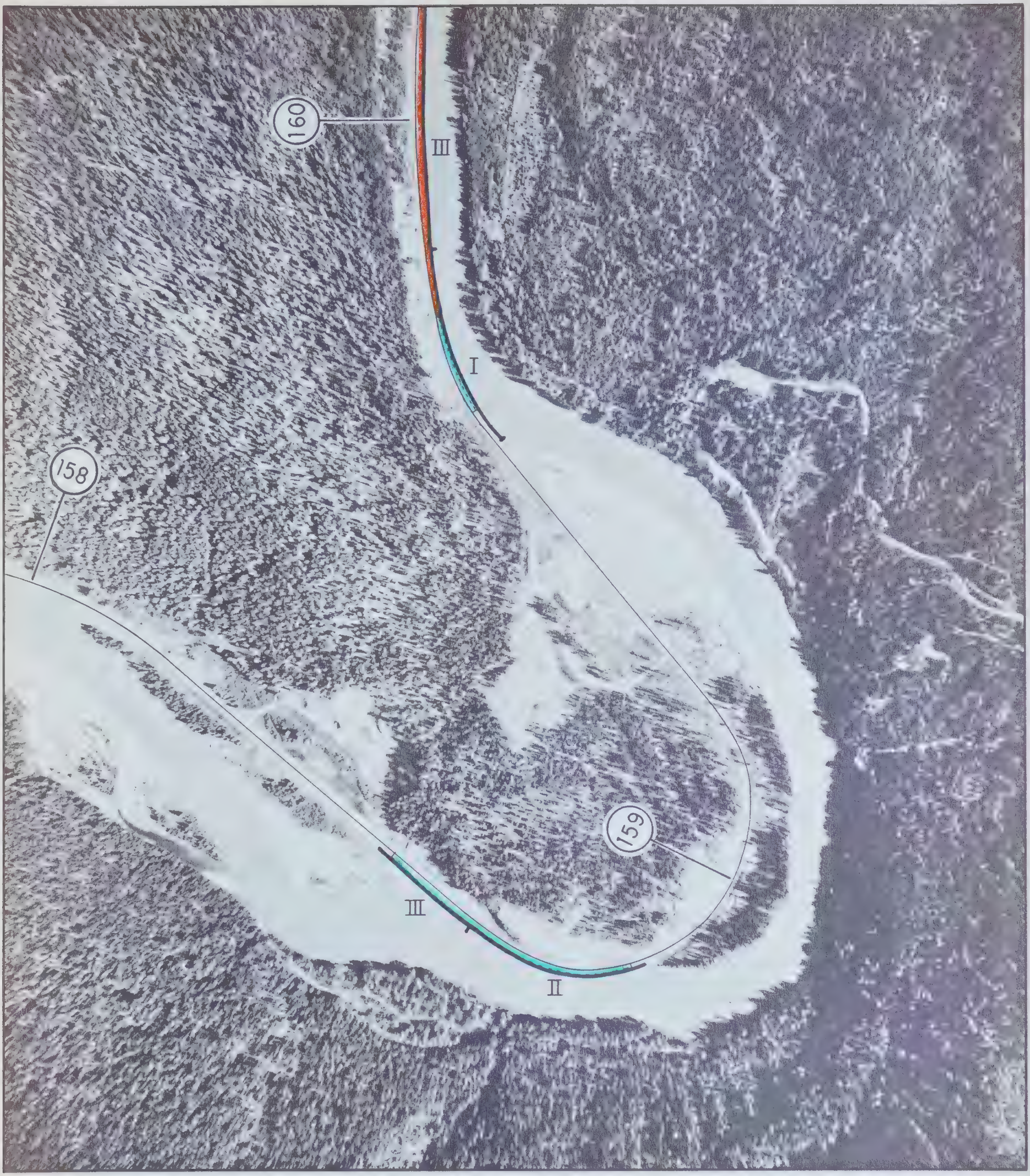
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972     SCALE 1'' = 800' (APPROX.)



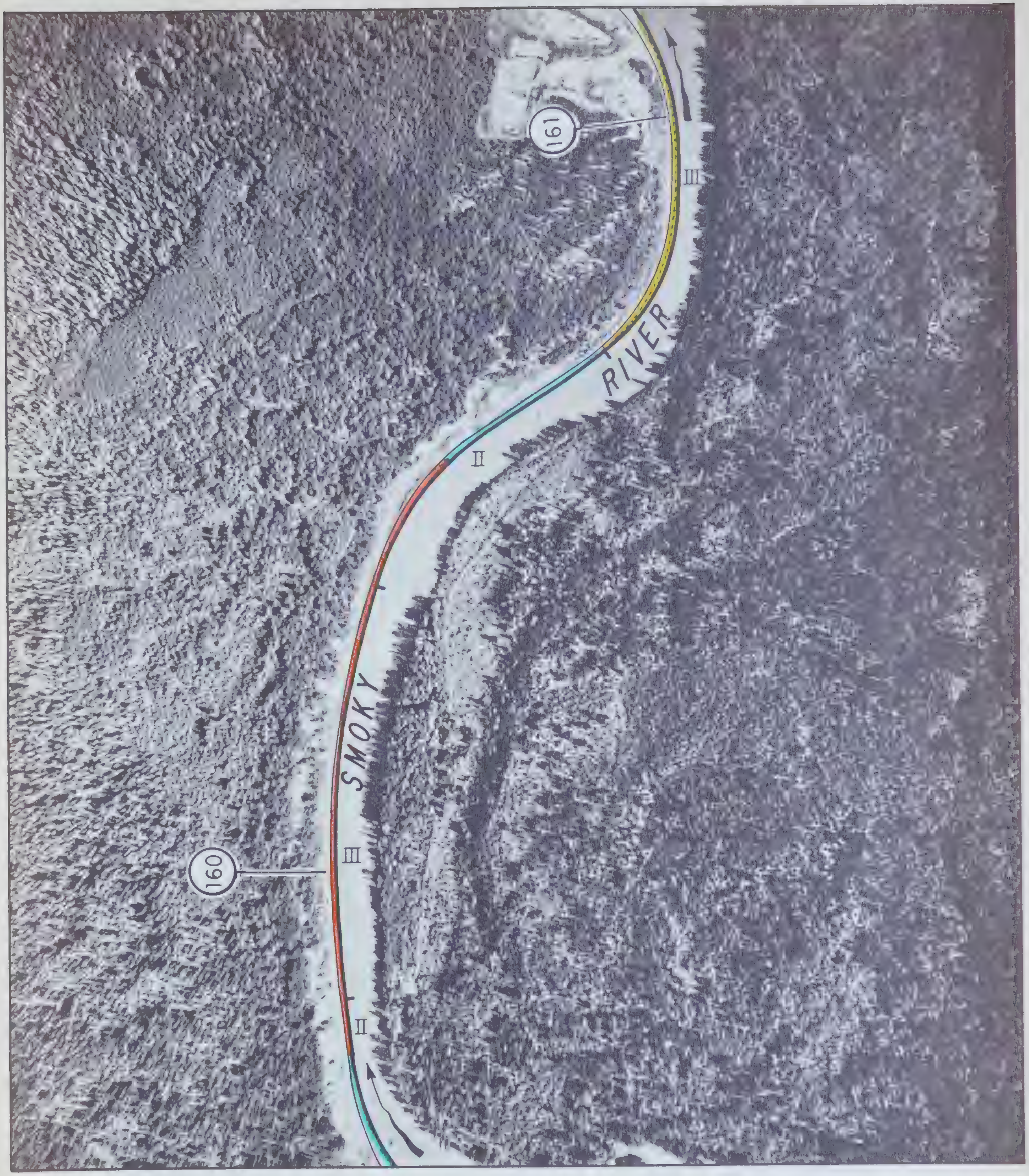
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

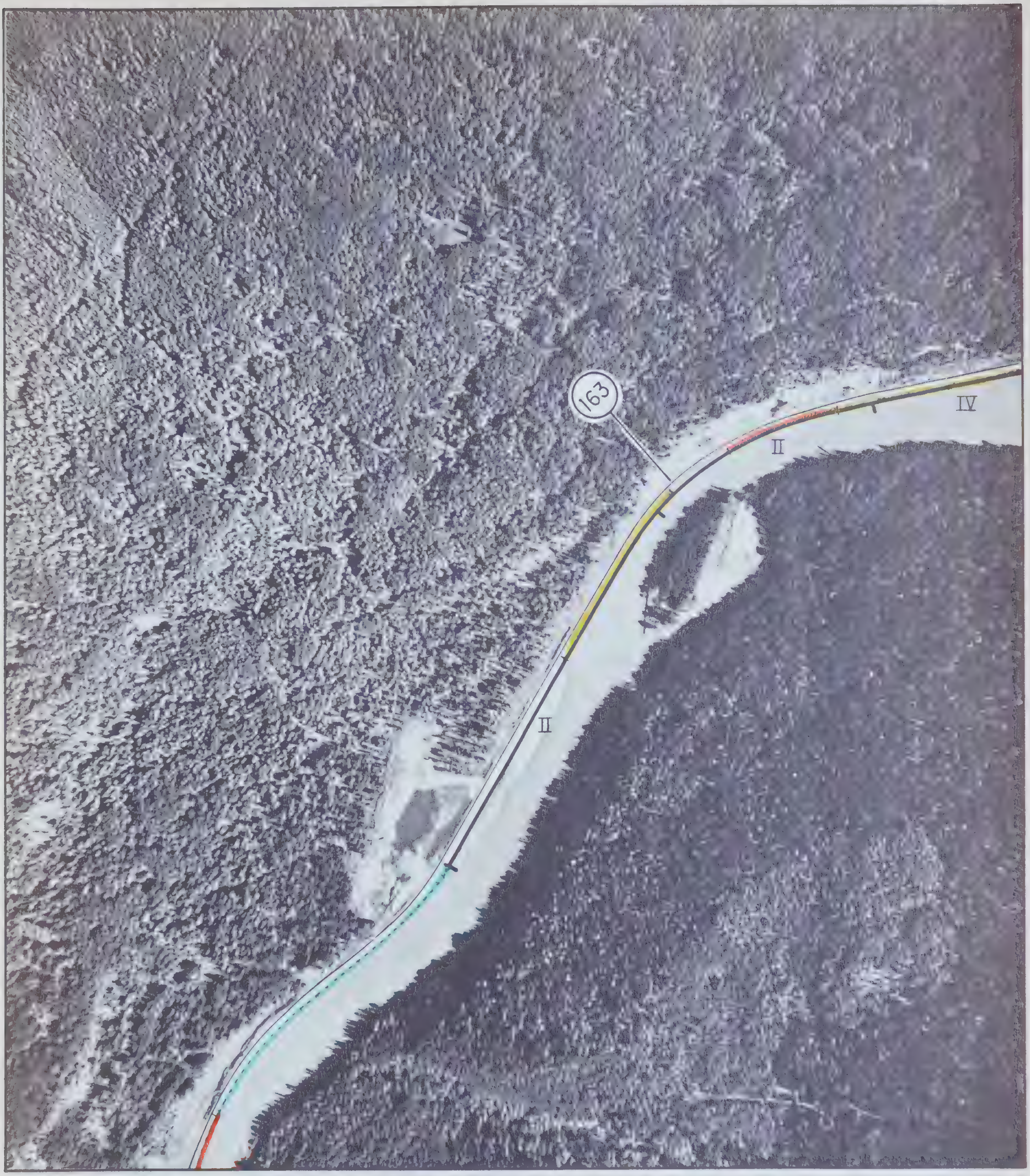
PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

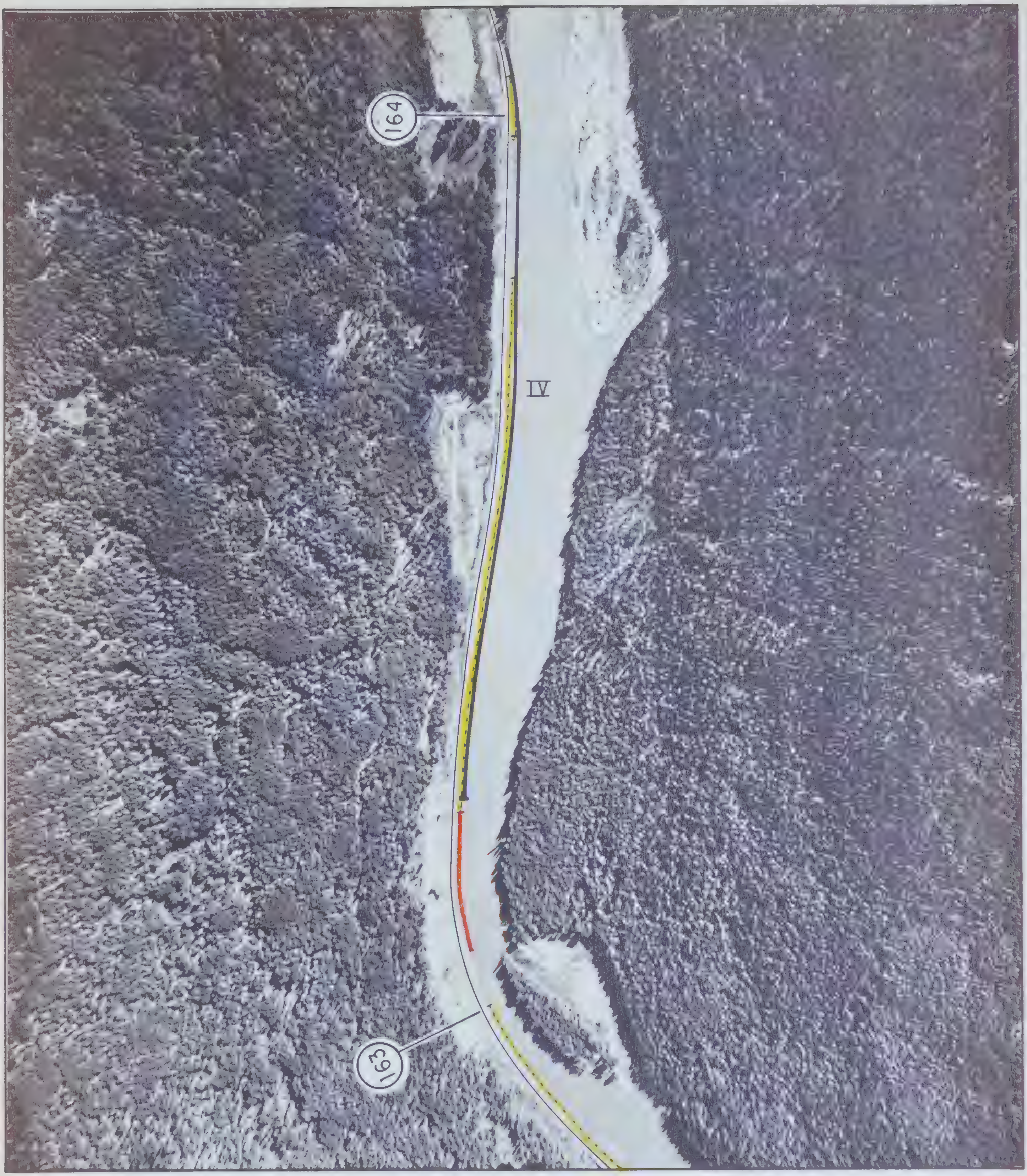
PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)

NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE. CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.



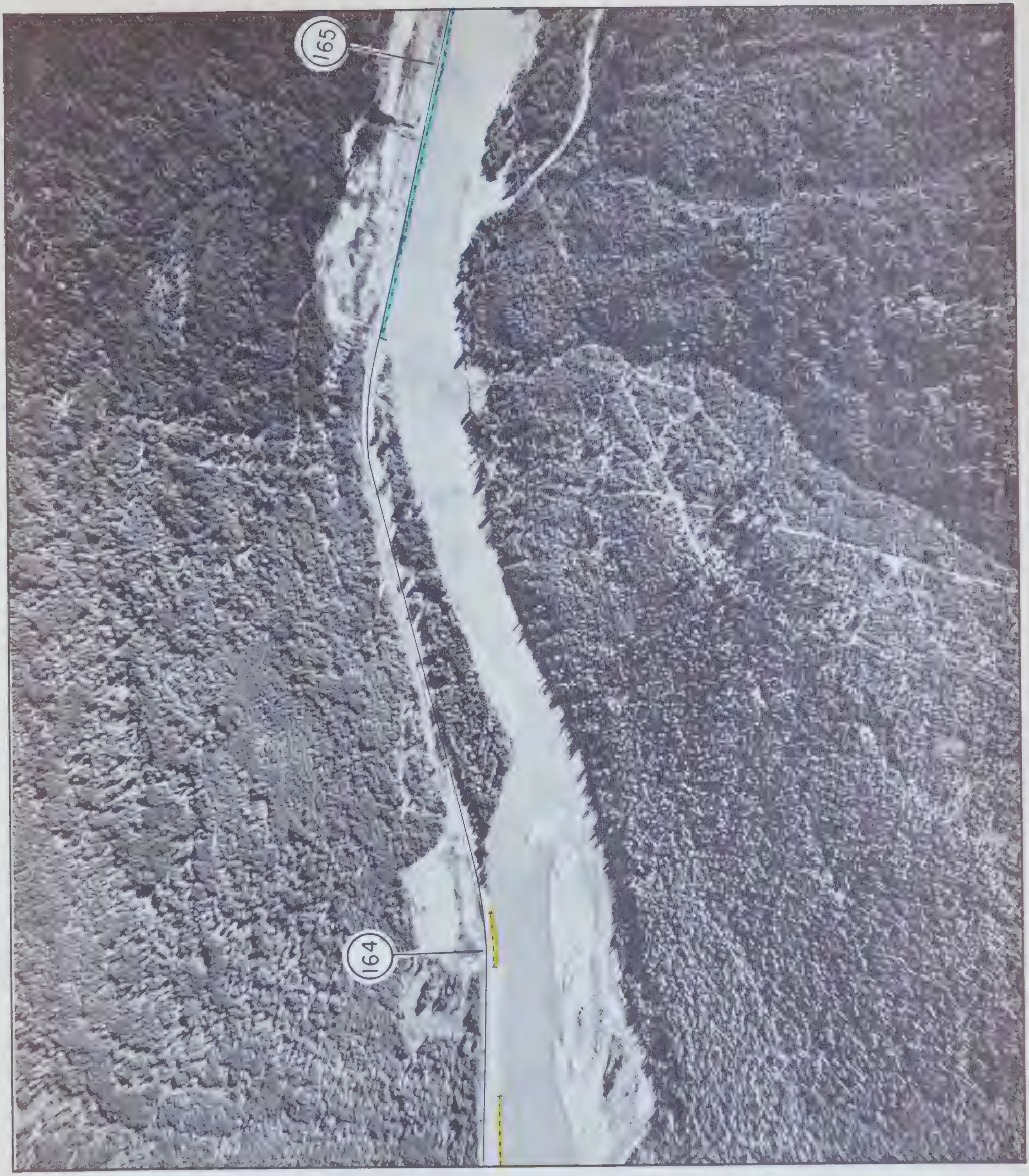
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 500' (APPROX.)



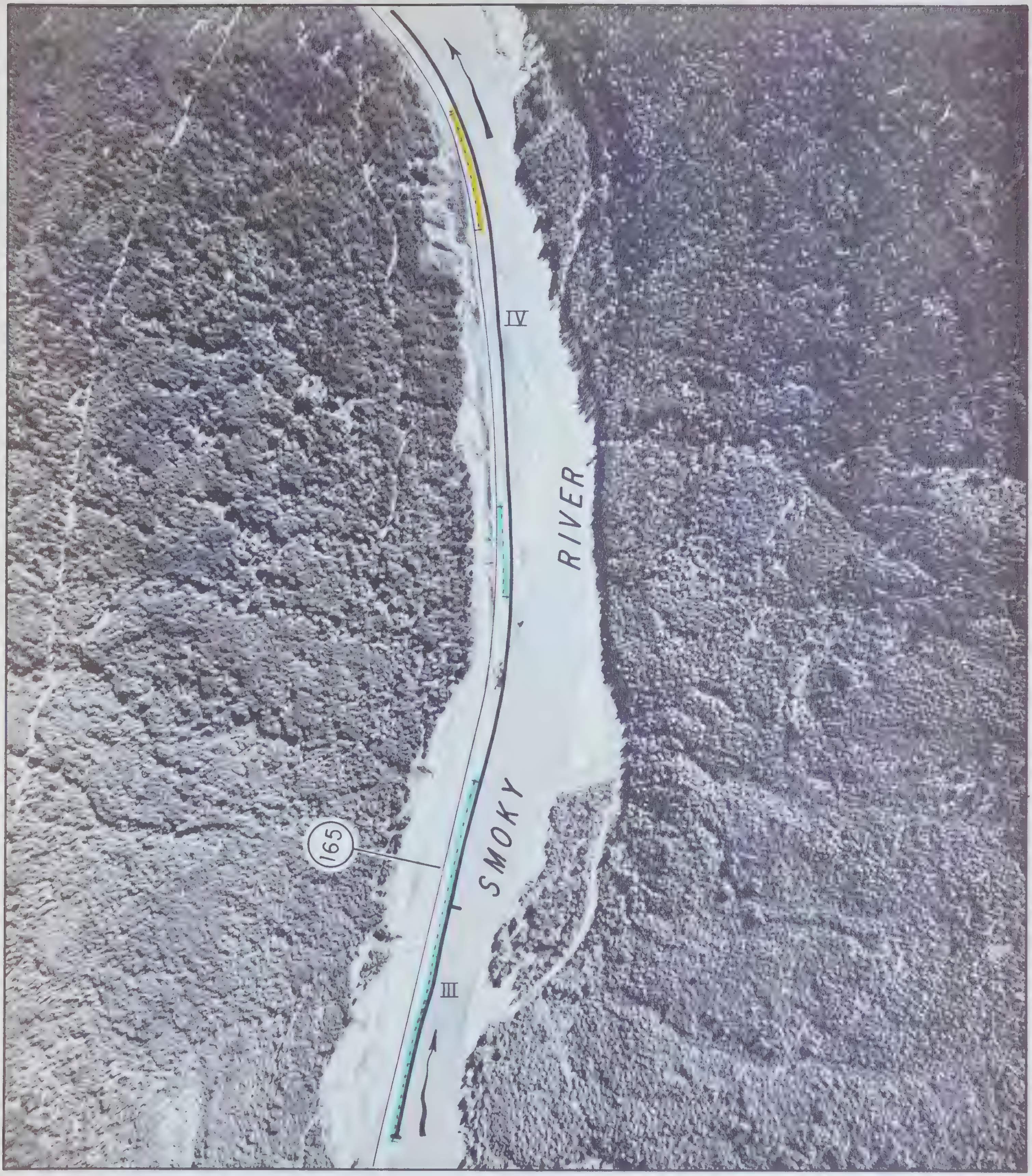
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 200' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

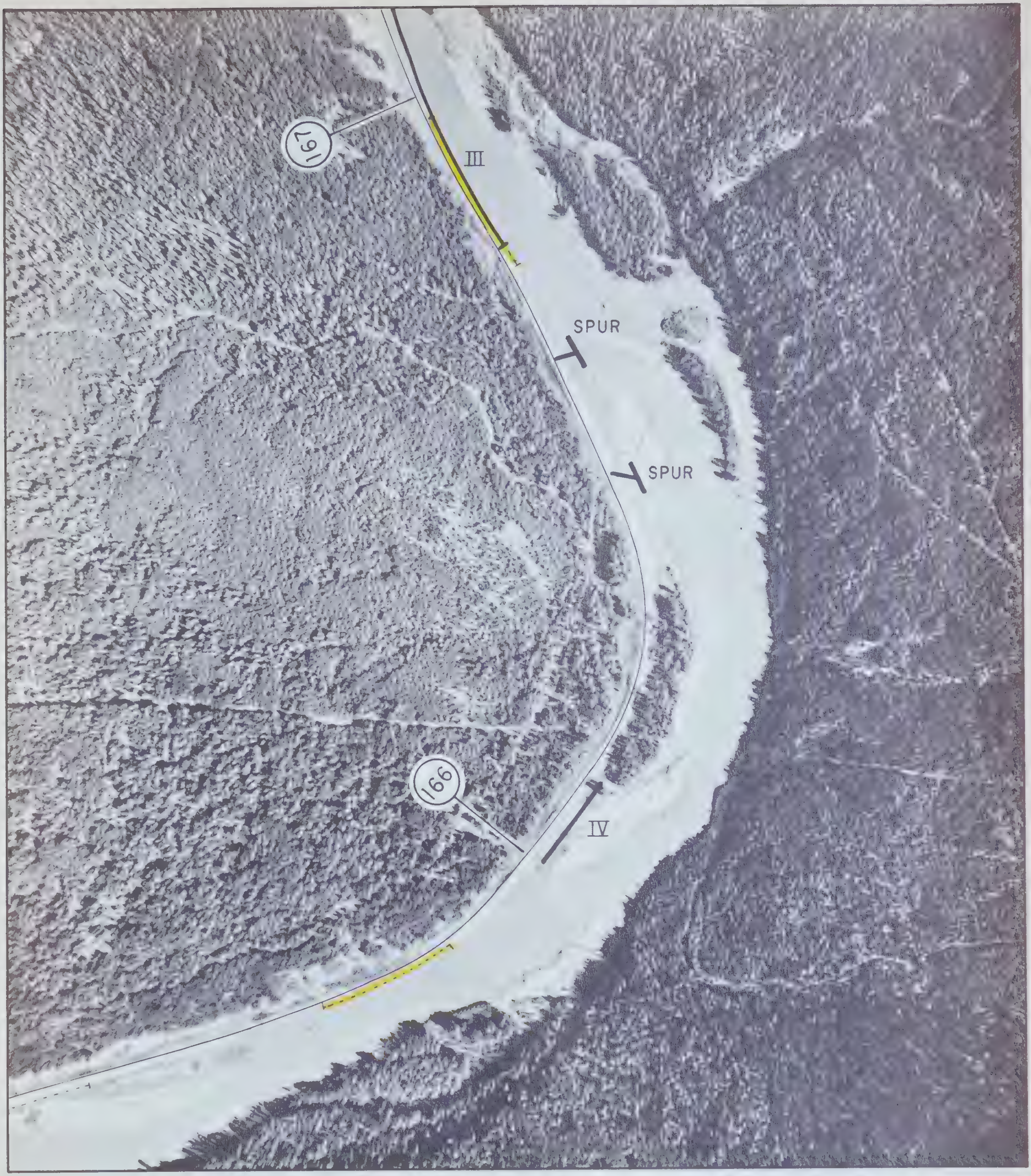
PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

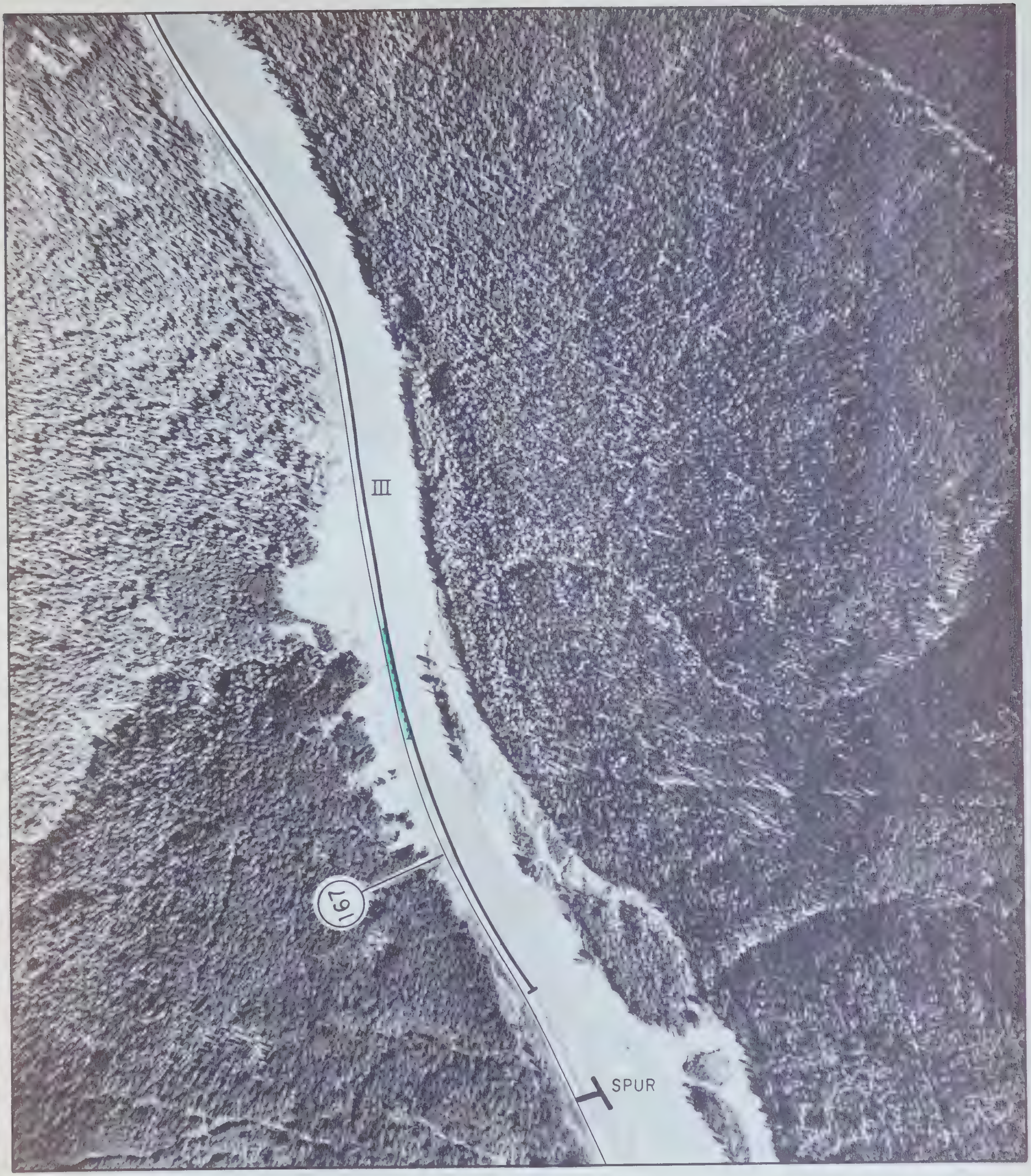
PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 500' (APPROX.)

NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE. CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.



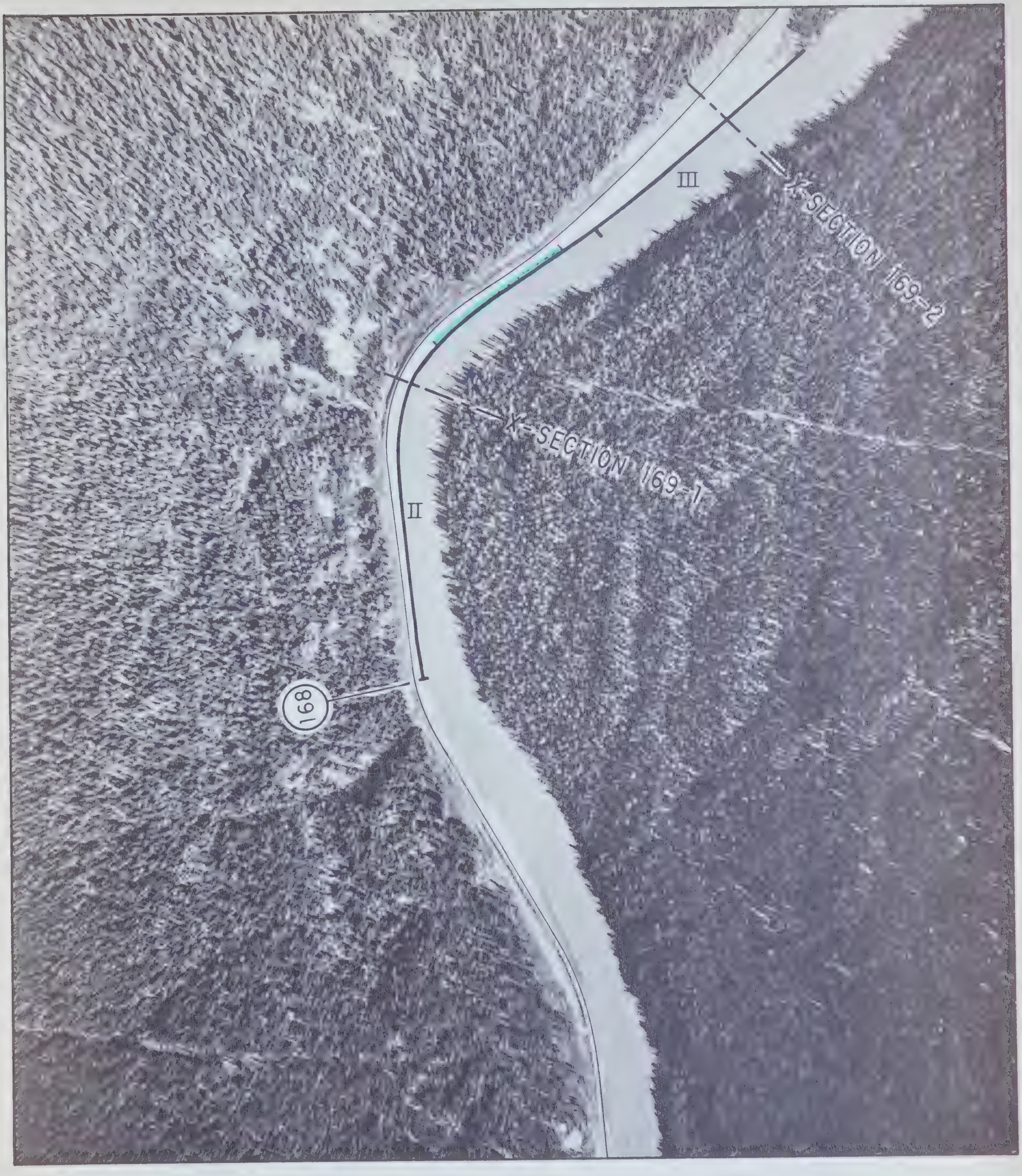
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)



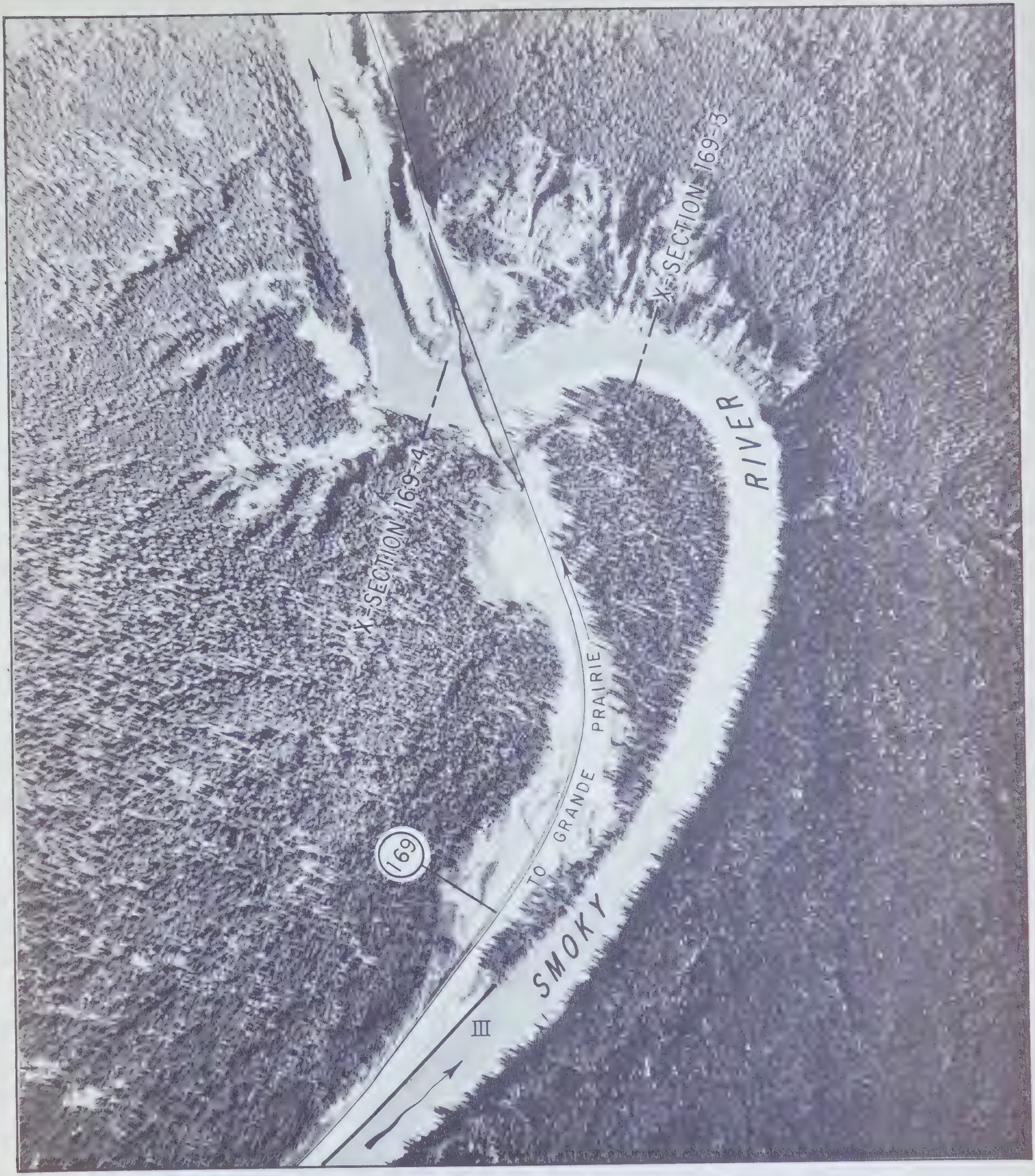
ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972    SCALE 1" = 800' (APPROX.)
NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972)    DISCHARGE ABOUT 2000 C.F.S.



ALBERTA RESOURCES RAILWAY - SMOKY RIVER BANK PROTECTION STUDY

PHOTOGRAPHY TAKEN JULY 1972 SCALE 1" = 800' (APPROX.)

NOTE: SEE PAGE A-1 FOR COLOUR KEY IN ASSESSING DEGREE OF DAMAGE ALONG RAILWAY GRADE. CIRCLED NOS. ARE MILEAGES ALONG TRACK. PAGE A-2 IS KEY MAP FOR LOCATION OF PHOTOGRAPHS.

NOTE: SURVEYED X-SECTIONS (NOVEMBER 1972) DISCHARGE ABOUT 2000 C.F.S.

# APPENDIX B

## Hydrology

# APPENDIX B

## Hydrology

B.1 It is important to establish some impression of how frequently one might expect a Smoky River flood equal in magnitude to the 1972 one. This task becomes difficult because of the scarcity of data available for the Smoky River particularily in its basin area above the Wapiti River confluence. One hydrometric station exists near Grande Cache where the upstream drainage area is 1,480 square miles and there are five years of discharge record, while a second station is located 200 river miles downstream at Watino where the drainage area is 18,500 square miles. The confluence of the Smoky River with the Peace River is only thirty-five miles below this last station. This station has twenty-four years of record but it is rather difficult to extrapolate this amount of data up to the headwaters area with any satisfactory degree of accuracy.

B.2 The Smoky River has its beginning on the eastward slopes of the Rocky Mountains about fifty miles northwest of Jasper. Grande Cache is some eighty river miles and 1,500 square miles downstream of this area. River bed ground elevations rise from 3200 feet (Geodetic) at Grande Cache to about 12,000 feet (Geodetic) at the upstream end of the basin. The line of the Alberta Resources Railway first crosses the Smoky River and begins running along the left bank and floodplain of the river at Mile 105. Sixty-four miles downstream the line rises out of the floodplain and crosses the Smoky River a second time over to the right valley wall. At this point the drainage area is 2,600 square miles and the

river bed elevation 2300 feet (Geodetic). Two major tributaries enter the Smoky River in this sixty-four miles; the Muskeg River at Mile 112 adding 388 square miles and Sheep Creek adding 361 square miles. The remaining 371 square miles of drainage area between Grande Cache and Mile 169 is made up of a succession of small, short basins (see Figure B.1) from which flood runoff would pass long before peak flows arrived from upstream.

B.3 1972 Storm; intensive rainfall in the Smoky, Wapiti basins began during the day of June 11, 1972. The process by which the large amount of rainfall precipitated was a combination primarily of two meteorological events; (1) frontal movements whereby two or more masses of air having different average densities and temperatures interact with each other causing horizontal and vertical movements of air. Generally the result is a warm moist air mass being forced to move up and over a colder air mass, so that in the process the cooling of the warmer air precipitates the moisture as rainfall, and (2) orographic uplift of a warm air mass whereby the horizontal movement of this air mass into foothill and mountain regions causes a vertical shift, a rapid cooling and consequently precipitation as the water-holding capability of the air is decreased.

As of June 11th the surface air over most of Alberta was warm and highly saturated and a low pressure cool air mass was moving easterly over Washington and Southern British Columbia. A counter-clockwise circulation of air around this low was beginning to force the warm moist Alberta air westward in the central, north-west area of Alberta. This process was forcing the air to rise over the Foothills south-west of Grande Prairie.

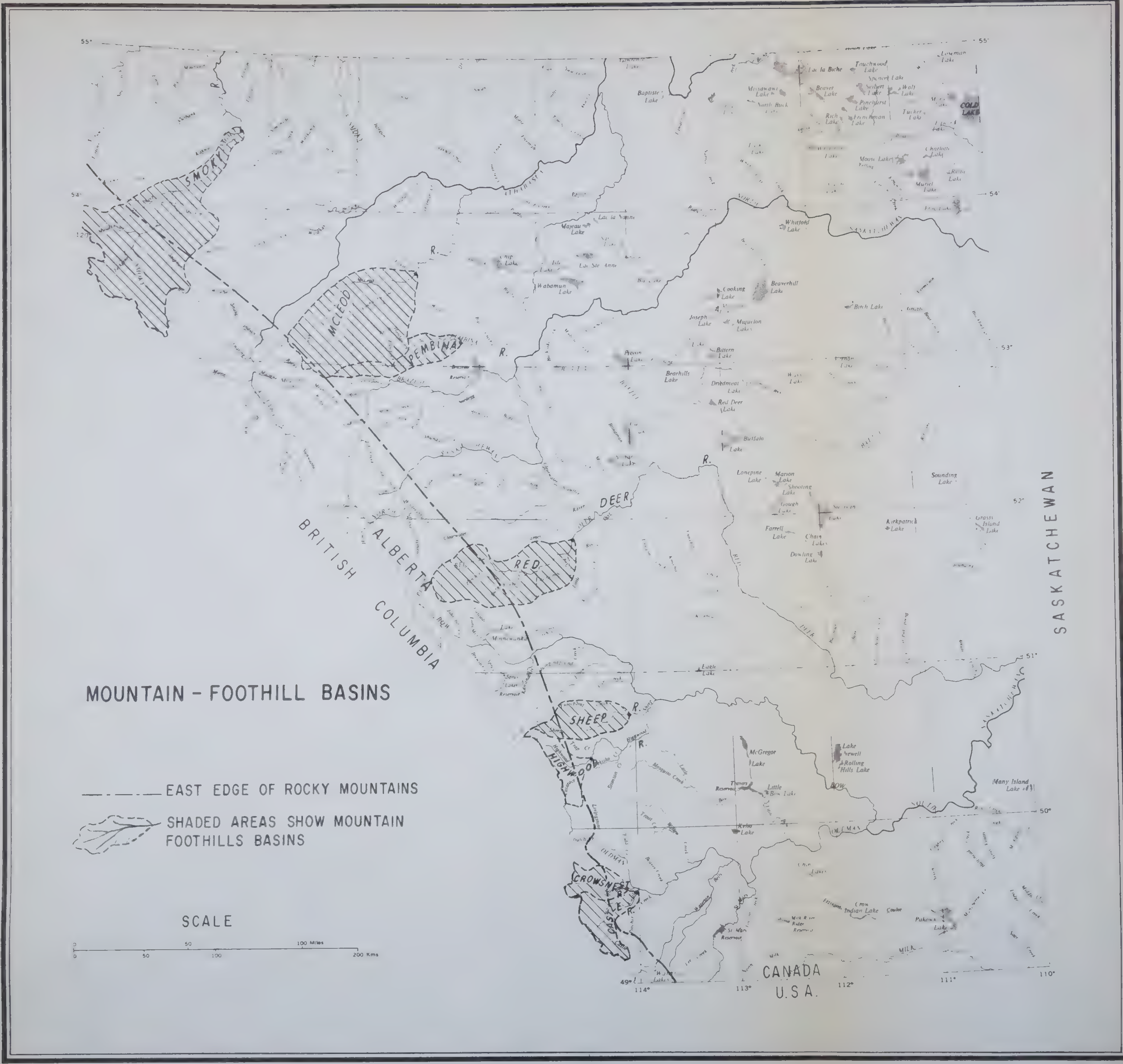

MOUNTAIN - FOOTHILL BASINS
EAST EDGE OF ROCKY MOUNTAINS
SHADED AREAS SHOW MOUNTAIN FOOTHILLS BASINS
SCALE
0 50 100 Miles
0 50 100 200 Kms
SMOKY
McLEOD
PEMBINA
RED
DEER
SHEEP
HIGHWOOD
CROWSNEST
CASTLE
R.
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
CANADA
U.S.A.
55°
54°
53°
52°
51°
50°
49°
120°
114°
113°
112°
111°
110°
Lac la Biche
Touchwood Lake
Beaver Lake
Baptiste Lake
COLD LAKE
Wabamun Lake
Lac Ste Anne
Isle Lake
Chip Lake
Cooking Lake
Beaverhill Lake
Joseph Lake
Miquelon Lake
Bittern Lake
Pigeon Lake
Bearhills Lake
Dried Meat Lake
Red Deer Lake
Buffalo Lake
Birch Lake
Whitford Lake
Lonepine Lake
Marion Lake
Shooting Lake
Gough Lake
Farrell Lake
Chain Lakes
Dowling Lake
Kirkpatrick Lake
Sounding Lake
Grassy Island Lake
Lake Minnewanka
Eagle Lake
McGregor Lake
Lake Newell
Rolling Hills Lake
Travers Reservoir
Little Bow Lake
Many Island Lake
Keho Lake
Crow Indian Lake
Pakowki Lake
St Mary Reservoir
Waterton Lakes
MILK
OLDMAN
BOW
SOUTH

FIG.- B.1

Throughout the latter part of June 11th and early part of June 12th the cooler dry air associated with the low moved north-easterly into the southern half of British Columbia and Alberta. By this time the upslope movement of the warm air over the Foothills and leading fronts of the Rockies was giving rise to large amounts of precipitation. The cold front associated with the low continued to move northward and then north-westward and by late June 12th had pinched off the supply of warm, moist air so that rainfall had by and large ceased in the Smoky and Wapiti basins by the evening of June 12th.

The result of these meteorological events was heavy rainfall over an area centered on Nose Mountain, fifty-five miles south-west of Grande Prairie. An isohyetal analysis of the measured rainfall from June 9 to June 13, 1972, is shown on Figure B.2. First order precipitation measuring stations were relatively scarce in the area and a large number of gaps exist where extrapolation of the curves was necessary. Most of the rainfall totals shown in Figure B.2 occurred during the 24-hour period 6:00 A.M., June 11 to 6:00 A.M., June 12. A Nose Mountain station (Elevation 5000 feet) recorded 6.5 inches of rainfall during this period while others were; Cutbank River, 5.7 inches; Torrens Lo, 5.0 inches; and Moberly Lo, 5.7 inches.

For comparative purposes, the writer suggests that the maximum-probable 24-hour point rainfall for the area is about 13 inches and the 100 year 24-hour point rainfall event is about 7.5 inches. It is suggested therefore that the 1972 storm in some areas produced some fairly rare rainfall intensities.

B.4 Storm Coverage; the heaviest amounts of rainfall fell in the Upper Wapiti, Cutbank and Kokwa basin areas. A line drawn through the

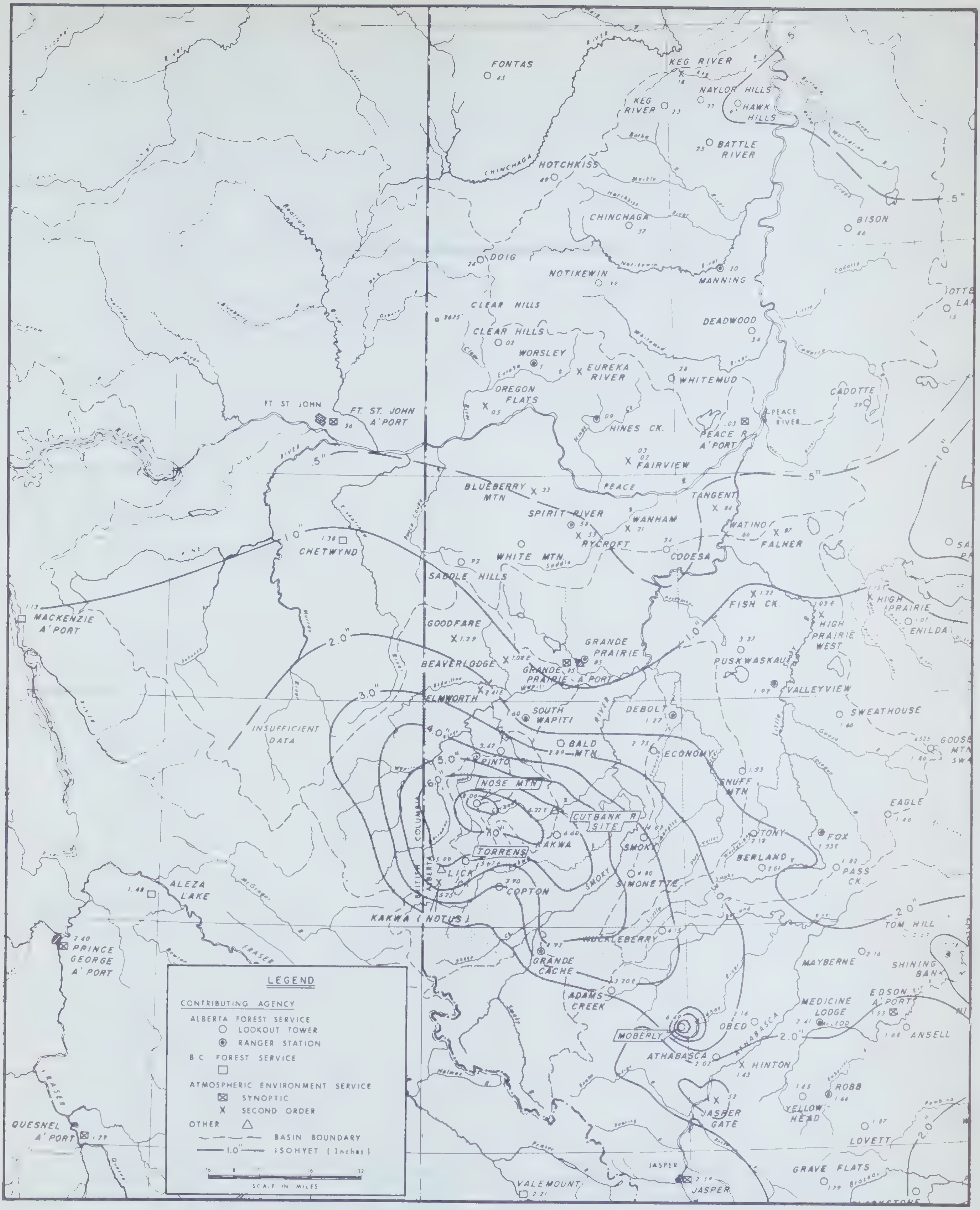


Fig. B.2: Isohyetal analysis for the period 1400 MDT, June 9 to 1400 MDT, June 13 except at AES synoptic stations where precipitation values are for the period 1200 MDT, June 9 to 1200 MDT, June 13. E indicates estimated value. Most precipitation fell in a NW-SE oriented band over the foothills east of the front ranges.

*Taken from preliminary report "Peace River Basin Flood, June, 1972." Canada Department of Environment, Inland Waters.

longitudinal axis of the isohyetal lines on Figure B.2 would be orientated in a north-west, south-east direction along the eastern (front) range of the Rocky Mountains. The bulk of rainfall fell in what would be considered the Foothills having ground elevations of 5000 feet and less, while the mountain areas in the upper Sheep Creek and Smoky River basins (ground elevations up to 12000 feet) received relatively much less total rainfall. Therefore considering the location, intensity, duration and apparent frequency of rainfall supplied by the 1972 storm over the South-Peace basin on June 11, 12, one would expect a fairly high flow from that area of the Smoky River above Grande Cache, extreme runoff events from the Wapiti, Cutbank and Kakwa basins, with Sheep Creek runoff volumes lying somewhere in frequency between that of the Kakwa and Sheep River basins.

B.5 Runoff; a hydrograph was estimated for that reach of the Smoky River below Sheep Creek. The primary inputs in deriving this hydrograph were the flows from the Muskeg River, Sheep Creek plus the Smoky River flow measured at Hells Creek near Grande Cache. Figure B.3 is the estimated constructed hydrograph for the Smoky River and was derived by adding up the three hydrographs below it. The slope-area method was used to estimate a peak of 28,000 cfs by Sheep Creek, while the Muskeg River discharge was recorded upstream of its confluence.

Figure B.3 suggests that the Smoky River reached a maximum discharge of 84,000 cfs in the early morning of June 12th. For design purposes the hydraulic computations assumed a discharge of 85,000 cfs for the entire reach of the Smoky River below Sheep Creek to Mile 169. As suggested previously the short basins in this reach would have given up their flood runoff volumes long before the peak arrived from upstream.

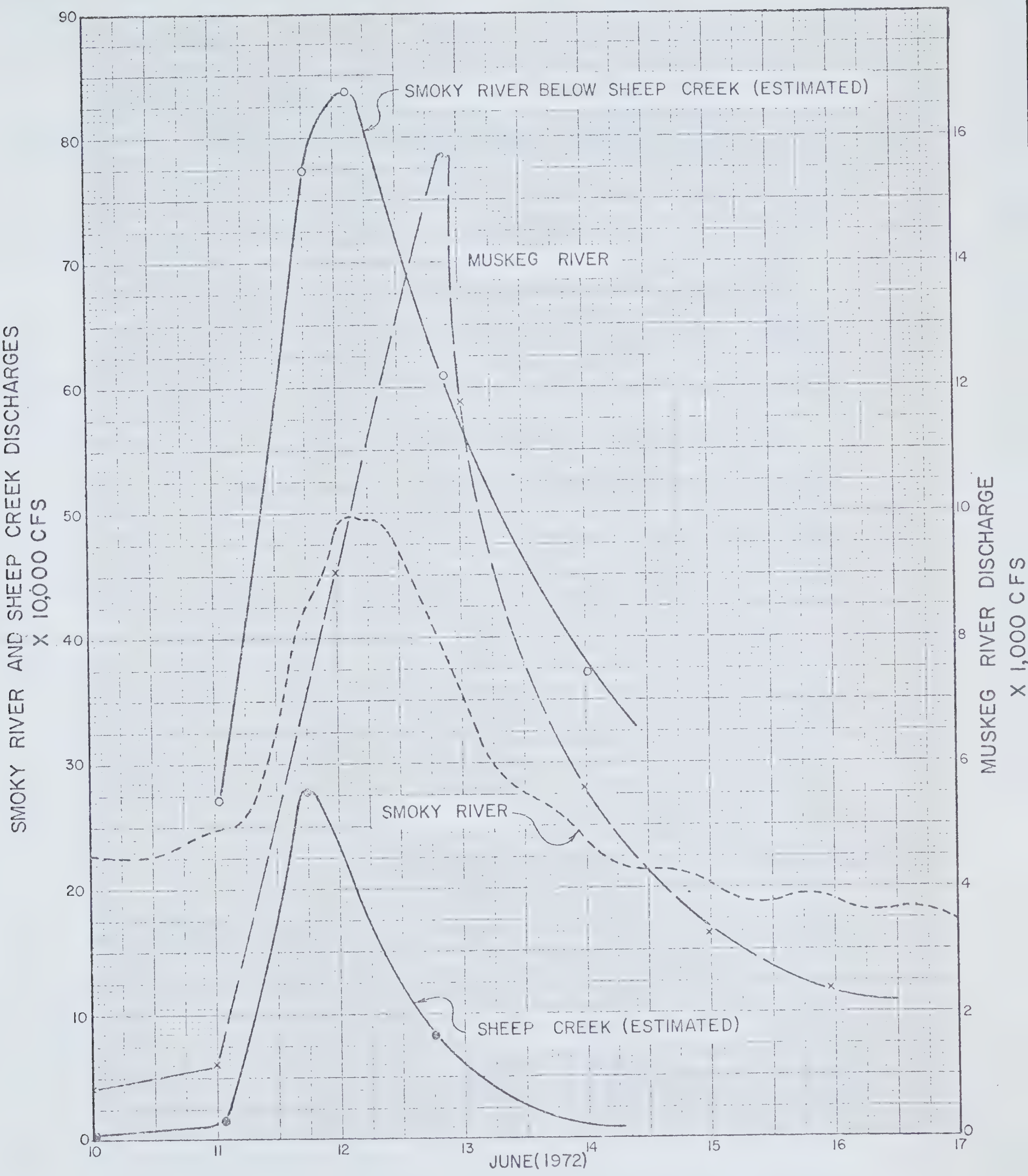
It is interesting to note that the Muskeg River did not peak until about twenty hours after the Smoky River which would have helped to sustain a near peak flow in the Smoky River.

Inches of runoff from various basins were computed for consideration as follows:

| River | Drainage Area (mi$^2$) | Inches of Runoff (inches) |
|---|---|---|
| Smoky River above Hells Creek | 1,480 | 1.9 |
| Muskeg River | 388 | 3.8 |
| Sheep Creek | 361 | 4.4 |
| Cutbank River | 315 | 4.4 |
| Smoky River above Mile 169 | 2,600 | 2.2 |
| Wapiti River near Grande Prairie | 4,350 | 3.7 |

The effect of the mountain region above Hells Creek on the inability of the orographic uplift processes to produce large amounts of rainfall beyond the first range of mountains (spillover) is somewhat apparent from the above values of runoff. The southern arm of the Smoky River extends almost parallel to an imaginary line running along the front range of the Rockies but thirty miles removed. Although the upper basin area is comprised of steep mountain slopes, much of it void of vegetation, the amount of spillover from the rare storm event to the east only produced 1.9 inches of runoff, while a heavily vegetated basin such as the Muskeg one produced twice as much runoff or 3.8 inches.

B.6 Flood Peak Frequency Analysis; It is impossible to carry out any direct statistical analysis for flood peaks on the small amounts of data available for the Smoky River basin in the Foothills region. It is therefore necessary to do a regional study where similar basins with



ESTIMATION OF FLOOD HYDROGRAPH FOR SMOKY RIVER BELOW SHEEP CREEK (MILE 115, A.R.R.)

FIG.-B.3

reasonably long flow records are used to produce empirical relationships of runoff and frequency.

The writer's attempt at doing this is shown on Figure B.4 where unit runoff in cfs per square mile is plotted against drainage area in square miles. Rivers used in the analysis are indicated on this plot and unit discharges are for instantaneous peaks.

It was felt that the slope of the best-fit line was fairly obvious but their vertical position within the plotted points takes careful consideration. The Crowsnest River points were not seriously considered as being representative because its basin is completely mountainous. Considerable weight was given to the Red Deer, McLeod and Pembina River basins because of their close proximity and similarity to the Smoky River basin. The points for the higher frequency values become more widely scattered and the line fitting more tenuous. Accepting these lines as reasonably representative of the hydrology in the post-mountain (Foothills) basins the following flood-frequency values are derived:

| | 50 Year (cfs) | 100 Year (cfs) | 1972 Peak (cfs) |
|---|---|---|---|
| Smoky River above Mile 169 | 73,000 | 91,000 | 85,000 |
| Sheep Creek | 14,500 | 18,000 | 28,000 |
| Cutbank | 12,600 | 15,700 | 27,000 |
| Muskeg | 15,100 | 18,600 | 15,700 |

These values would suggest that:

1. The 1972 flood peak through that reach of the Smoky River which destroyed so much A.R.R. track was at least a fifty year event and likely not more than a 100 year one.

2. The Sheep Creek 1972 peak was likely an event which has a probability of occurring which is beyond a 100 year return period.
3. The Muskeg River peak has a return period of around once in fifty years.
4. Both the Sheep Creek and Cutbank River peaks suggest that the basins in the area around the centre of the 1972 storm experienced rare flood events which had return periods of at least 100 years.

B.7 A plot which provides some further insight into the expected frequency of runoff experienced by basins in the upper Smoky basins is given in Figure B.5. All historic peaks recorded for Alberta Rivers are plotted as unit runoff (cfs/square miles) versus drainage area ($mi^2$), and an upper envelope curve has been drawn above these plotted points. No particular frequency can be assigned to values along this line but since the recorded peaks have occurred in the last seventy years one might expect that these peaks should be expected to occur within a normal life-time period. The 100 year line from Figure B.4 has been plotted on Figure B.5 and it is interesting to note that the points which lie well above this 100-year line are from two basins; the Oldman and Peace River. Those from the Oldman basin occurred as a result of the 1964 storm which produced catastrophic floods in Northern Montana and record floods in South-Western Alberta. The Peace River points were those from the 1972 storm. Again it shows that the smaller tributary basins of the Smoky River which extended into the high rainfall areas of the 1972 storm experienced floods which had return periods beyond a

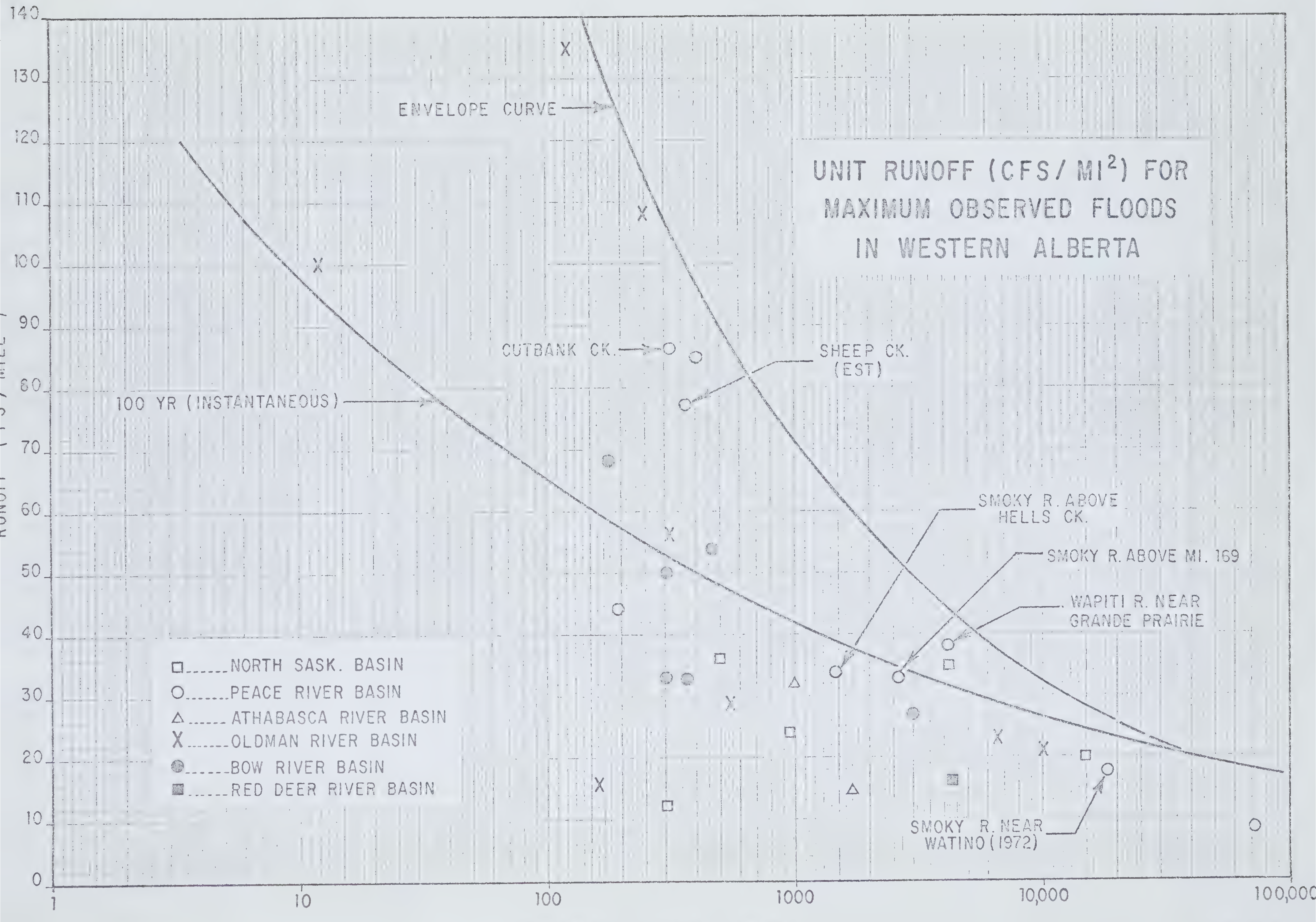

UNIT RUNOFF (CFS/MI²) FOR
MAXIMUM OBSERVED FLOODS
IN WESTERN ALBERTA
ENVELOPE CURVE
100 YR (INSTANTANEOUS)
CUTBANK CK.
SHEEP CK. (EST)
SMOKY R. ABOVE HELLS CK.
SMOKY R. ABOVE MI. 169
WAPITI R. NEAR GRANDE PRAIRIE
SMOKY R. NEAR WATINO (1972)
□ NORTH SASK. BASIN
○ PEACE RIVER BASIN
△ ATHABASCA RIVER BASIN
X OLDMAN RIVER BASIN
● BOW RIVER BASIN
■ RED DEER RIVER BASIN
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
10,000
100,000
DRAINAGE AREA (MILES²)
RUNOFF

FIG-B 5

100-year return period but the Smoky River itself adjacent to the A.R.R. track from Mile 105 to Mile 169 likely had a peak that was likely not greater than a 100-year one.

# APPENDIX C

## Hydraulic Analysis

# APPENDIX C

## Hydraulic Analysis

C.1 In order to obtain some idea of the magnitude of hydraulic variables which would have to be dealt with in the design of the embankment and bank protection, nine reaches of the Smoky River between Mile 115 and Mile 169 were surveyed in the first week of November, 1972. Cross-sections were surveyed in each of these reaches and their locations are shown on the air photographs in Appendix A. Plotted cross-sections are presented at the end of Appendix C (Figure C.1) and on these plots, where the embankment has been totally or wholly removed by the 1972 flood, the estimated original configuration of the embankment outline has been drawn. Also highwater marks were located in the field and where available have been plotted along with the cross-sections.

C.2 Hydraulic Computations; the surveyed cross-sections were used to compute estimates of the 1972 peak discharge. A constant longitudinal channel slope of 0.0021 was assumed and on the average the results were reasonably close to the peak of 85,000 cfs estimated in Appendix B. Because of the constrictions in width imposed by the presence of the A.R.R. embankment in many reaches, and the tight bends in the channel alignment, there were likely local large differences in water surface slope which weren't taken into account in the computations. For computational purposes it was assumed that the discharge in the Smoky River during the 1972 flood, which was primarily responsible for the damages which occurred to the A.R.R. was 85,000 cfs.

Table C.1 is a summary of observations made using the surveyed cross-sections, where:

TABLE C.1

## SUMMARY OF HYDRAULIC ANALYSIS OF SURVEYED CROSS-SECTIONS SMOKY RIVER

$V_M$ = Mean Channel Velocity

$V_{NM}$ = Estimated Mean Channel Velocity of natural channel (prior to A.R.R. construction)

$W_f$ = Water surface width from right bank of Smoky River to right edge of railway embankment, of 1972 flood.

$W_{Nf}$ = Water surface width from right bank of Smoky River to estimated natural left bank of 1972 flood.

$d_t$ = Depth of flow from 1972 flood level to deepest part of section.

| Mile -No. | $V_M$ (Ft/Sec) | $V_{NM}$ (Ft/Sec) | $W_f$ (Ft) | $W_{Nf}$ (Ft) | $d_t$ (Ft) |
|---|---|---|---|---|---|
| 117 - 1 | 12.1 | | 610 | 710 | 18 |
| 2 | 9.7 | | 485 | 510 | 18.5 |
| 3 | | | 400 | 440 | 15 |
| 4 | 7 | | 410 | 440 | 22.5 |
| 121.8- 1 | 11.3 | 10.7 | 380 | 410 | 23 |
| 2 | 17.5 | 16.6 | 280 | 320 | 26 |
| 3 | 16.1 | 15.7 | 350 | 340 | 23 |
| 4 | 15.2 | 15.0 | 380 | 380 | 17 |
| 130 - 1 | 12.1 | 10.8 | 320 | 380 | 25.5 |
| 2 | 16.2 | 12.8 | 240 | 310 | 27.5 |
| 3 | 11.6 | 10.5 | 370 | 420 | 24 |
| 4 | 17 | 14 | 220 | 305 | 28 |
| 5 | 13.3 | 9.8 | 305 | 420 | 24 |
| 118.3- 1 | 12.1 | 12.1 | 450 | 450 | 20 |
| 2 | 12.4 | 12.4 | 400 | 400 | 21 |
| 3 | 13.0 | 13.0 | 355 | 355 | 22 |
| 4 | 13.0 | 13.0 | 340 | 340 | 22 |
| 136 - 1 | 12.3 | 10 | 630 | 760 | 18 |
| 2 | 10.7 | 7.8 | 580 | 850 | 18 |
| 3 | 10.2 | 9 | 660 | 750 | 19 |
| 4 | 10.8 | 10.2 | 660 | 750 | 16 |
| 5 | 12.2 | 10.8 | 500 | 570 | 24 |
| 6 | 10.9 | 10.3 | 330 | 440 | 19 |
| 7 | 12 | 12.9 | 480 | 540 | |

TABLE C.1 cont.

| Mile -No. | $V_M$ (Ft/Sec) | $V_{NM}$ (Ft/Sec) | $W_f$ (Ft) | $W_{Nf}$ (Ft) | $d_t$ (Ft) |
|---|---|---|---|---|---|
| 144 - 1 | 11.5 | 9.5 | 450 | 640 | 21 |
| 2 | 10.9 | 10.2 | 490 | 550 | 20 |
| 3 | 13.5 | 12.4 | 360 | 400 | 26 |
| 4 | 12.9 | 12.2 | 450 | 500 | 20 |
| 5 | 9.1 | 8.8 | 490 | 550 | 25 |
| 6 | 14.6 | 13.3 | 290 | 325 | 26 |
| 7 | 11 | 10.2 | 400 | 480 | 22 |
| 155 - 1 | 11.9 | 10.6 | 310 | 390 | 33 |
| 2 | 16.8 | 15.5 | 265 | 340 | 25 |
| 161.5- 1 | 17.5 | 16.5 | 280 | 310 | 22 |
| 2 | 11.5 | 11.5 | 495 | 495 | 21 |
| 3 | 16 | 16 | 340 | 340 | 27 |
| 4 | 22 |  | 310 |  | 23 |
| 5 | 13.7 |  | 370 | 380 | 22 |
| 169 - 1 | 9.9 |  | 360 |  | 29 |
| 2 | 14 |  | 375 |  | 21 |
| 3 | 11.6 |  | 400 |  | 24 |
| 4 | 10.7 |  | 400 |  | 26 |

$V_M$ - is the mean channel velocity obtained by dividing the flood discharge by the cross-sectional area under the estimated flood water-surface.

$V_{NM}$ - is the mean channel velocity using the estimated original channel section (without A.R.R. embankment) where the embankment has been wholly or partly located within the natural floodway of the Smoky River.

$W_f$ - is the flood water surface width measured from the right bank of the river to the right edge of the A.R.R. embankment. In some cases there was a floodplain beyond the right bank but it was usually so heavily forested that relatively small amounts of flow would have passed through it.

$W_N$ - is the estimated flood water-surface width that would have occurred without the presence of the railway embankment. It is one measure of the amount of constriction caused by the embankment.

$d_t$ - maximum depth of flow in a section measured from the 1972 flood level.

Where the channel is braided or has a low, wide floodplain (eg. Sections at Mile 117) the mean channel velocities were 7-12 ft./second and channel width 400-600 feet, with the embankment not having any noticeable constricting effect.

In the reaches where the channel was relatively straight (Mile 118) with a fairly high floodplain on the right side, mean channel velocities were 12-13 feet/second and channel widths 350-450 feet.

Where the channel approached the A.R.R. embankment at a small angle of incidence (10-15°) such as at Mile 136 the mean velocity was about 12 feet/second. In this case the embankment constricted the channel from 570 to 500 feet (X-section 136-5, pp. A.32) and likely increased the mean velocity by about ten percent.

Where the channel approaches the embankment at a higher angle (45°) such as in Mile 144 and the channel was constricted, mean channel velocities were around 14 feet/second at the most constricted section (X-section 144-3). Here the channel width was reduced from 400 feet to

360 feet and velocities increased by ten percent. Further downstream in Mile 145 the angle of attack is about the same but channel width less. At X-section 144-6 the mean channel velocity was about 15 feet/second where the channel was constricted from a width of 325 feet to 290 feet and velocities subsequently increased by ten percent.

At a greater angle of attack (90°) such as in Mile 155, mean channel velocity was about 17 feet/second in the narrowest section where the width was shortened to 265 feet from 340 feet. Constricting the channel increased velocities by about ten percent.

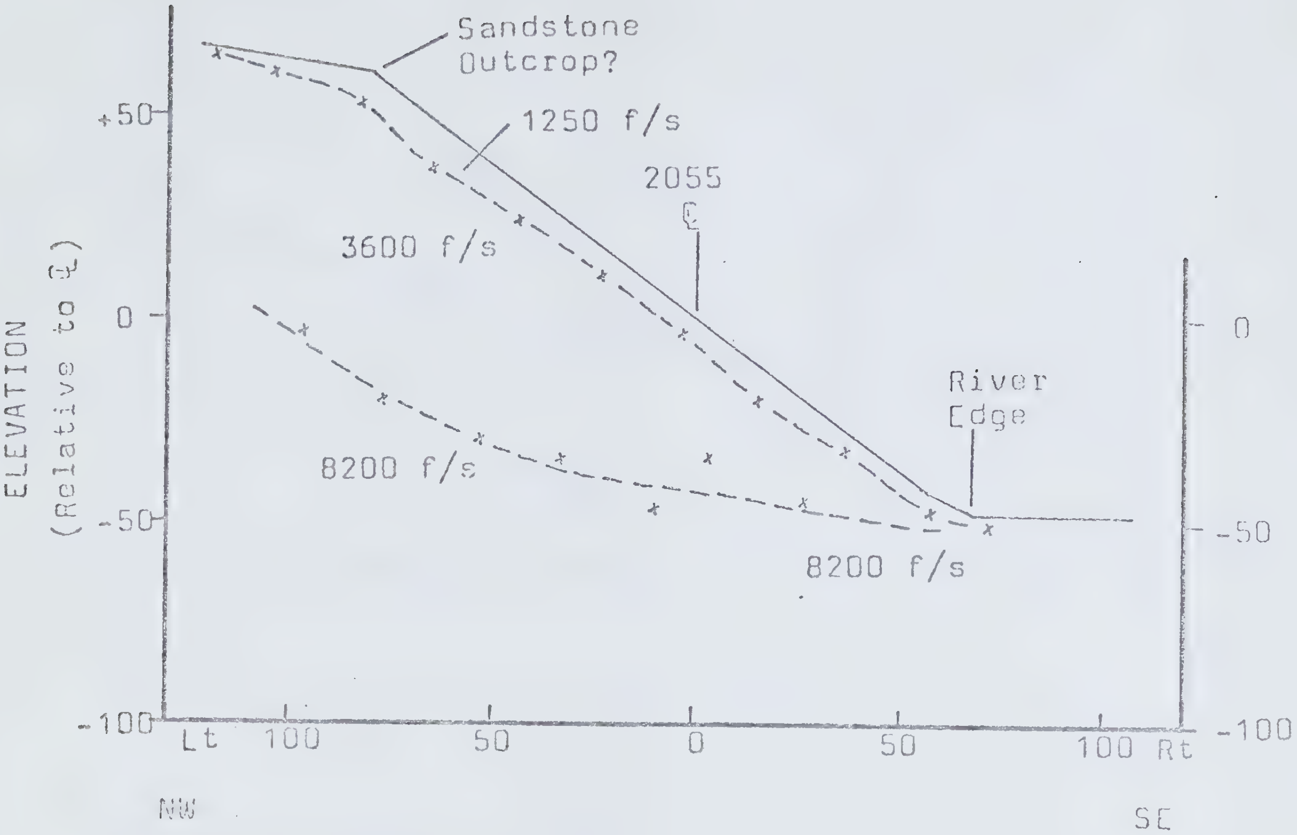
Where the A.R.R. embankment was attacked at an angle of greater than 90° such as in Mile 162 the mean channel velocity was 22 feet/second at X-section 161.5-4 (pp. A.58). Channel width was about 310 feet after construction, and it is impossible to estimate the natural width prior to construction because much of the channel in this reach was reconstructed to accommodate the alignment of the embankment through the center of the original channel.

C.3 Maximum depths of flow varied from 15 feet to 33 feet. Generally this depth of flow depended upon the angle of attack on the A.R.R. embankment, the width of the primary channel and the amount of floodplain available.

In a braided reach the maximum depth measured was 22.5 feet, which was about the same value measured in a straight, incised reach. Where there was some small angle (15°) of approach to the embankment and some channel constriction the maximum depth increased to 24 feet and if the angle of approach became larger (45°) this depth was about 26 feet. At the very tight bends maximum depths of 33 feet were measured.

It is difficult to speculate with any degree of reliability whether or not deeper scour holes had developed during the period of the 1972 flood. If larger depths did occur it is possible some of the holes partially filled in with gravel on the down-side of the flood-hydrograph. There is some strong evidence that the Smoky River in much of the reach being studied has degraded into bedrock. Note the results of seismic recordings in Figures C.2 to C.5 taken from a soils investigation report by R. C. Thurber and Associates Ltd. These profiles suggest that for the sections considered in these plots which are at the ends of fairly tight bends in the river, there exists bedrock just a few feet below the gravel bed of the river. This might explain the lack of any observed deep rooted scour holes along the toe of the embankment even at points of probable severe attack. Therefore at least in some reaches the river must move along a thin surface layer of gravel as bed-load, over a bedrock surface.

A measure of the potential maximum depths of flow which might have been expected during the flood was computed using Blench's regime depth formula and a "Z" factor of 1.7. The $F_b$ values were computed using the velocities and channel widths in Table C.1 and regime depths computed using the formula $d_R = (\frac{q^2}{F_b})^{1/3}$. By definition the largest depth one might expect in a natural channel which has a non-uniform section such as occurs at the outside of a bend is approximated by multiplying $d_R$ by 1.7. Table C.2 provides the results of the computations, where the depth of scour values ($d_S$) are the differences between $1.7 d_R$ and $d_t$(maximum measured depth). These scour values would provide some estimate of what might have been the amount of degradation during the flood below the observed bed levels if the river were not impeded by any bedrock surfaces. Further to this is the question of the bedrock's



MILE 148

SUGGESTED CLASSIFICATION

| Velocity | Material |
|---|---|
| 1250 f/s | Loose surficial cover |
| 3600 " | Weathered or disturbed Rock |
| 8200 " | Firm Sandstone |

LEGEND

x Seismic Depth

- - - Inferred Rock Boundary

Scale: 1"=50'

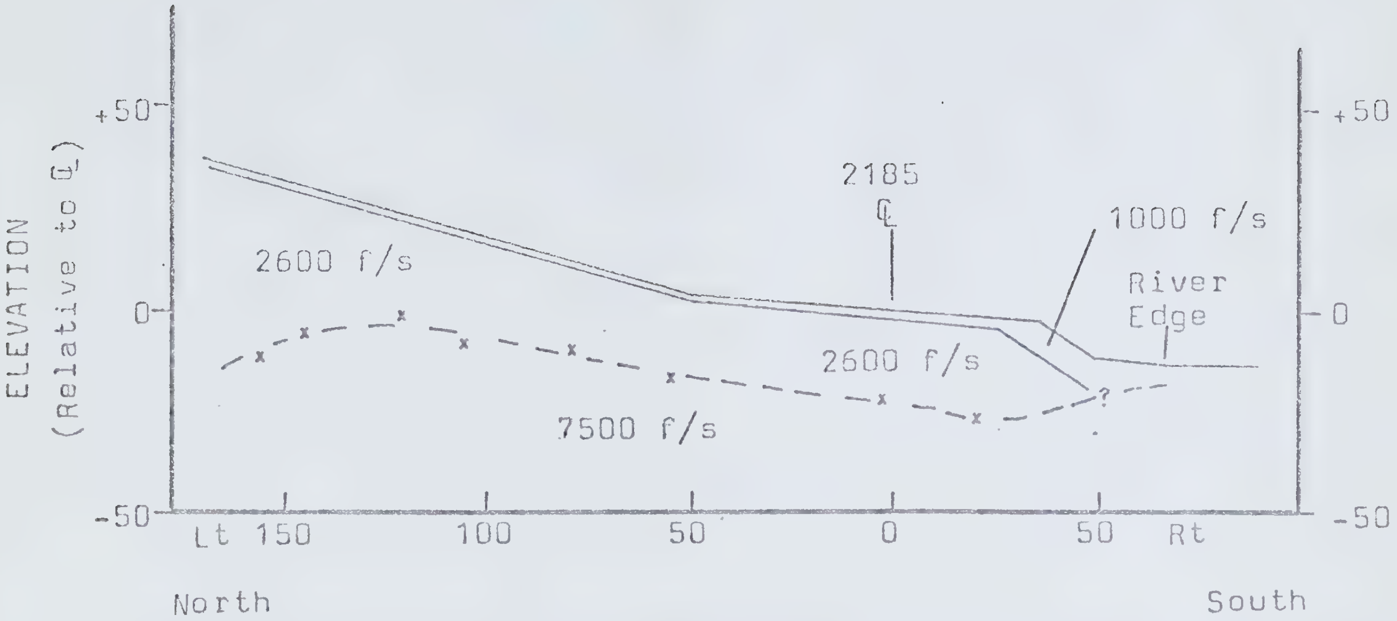
Geo-Recon Explorations Ltd.

ALBERTA RESOURCES RAILWAY
SECTION 7
SEISMIC PROFILE

CROSSLINE
2055+00

April, 1967
GX-52

FIG.-C.2



MILE 150.5

SUGGESTED CLASSIFICATION

| Velocity | Material |
|---|---|
| 1000 f/s | Loose Surficial Layer |
| 2600 " | Alluvium |
| 7500 " | Bedrock |

LEGEND

x Seismic Depth

--- Inferred Rock Boundary

Scale: 1"=50'

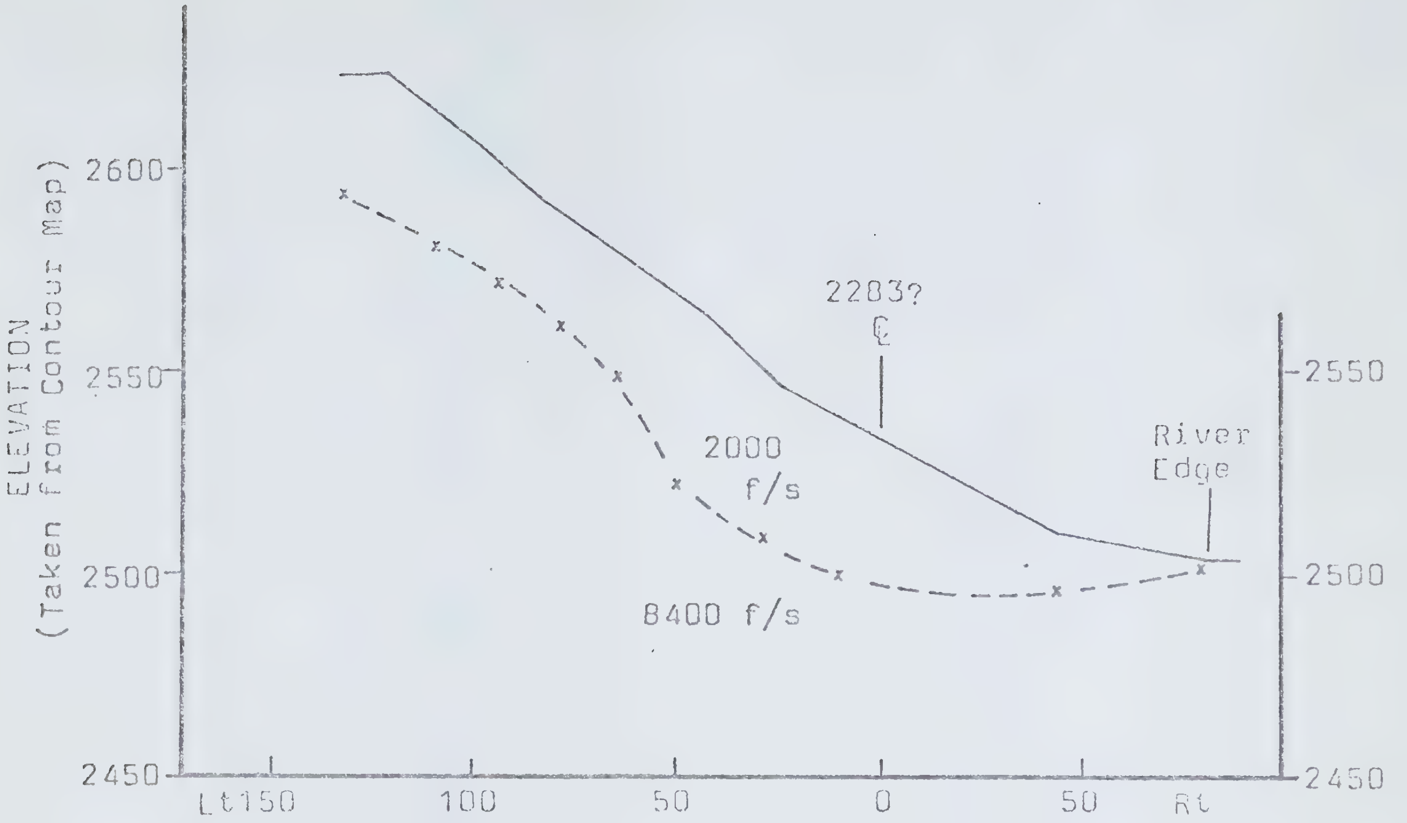
Geo-Recon Explorations Ltd.

ALBERTA RESOURCES RAILWAY
SECTION 7
SEISMIC PROFILE

CROSSLINE
2185+00

April, 1967

FIG.-C.3



MILE 152.3

SUGGESTED CLASSIFICATION

| Velocity | Material |
|---|---|
| 2000 f/s | Loose Material, Undifferentiated |
| 8400 " | Firm Bedrock |

LEGEND

x Seismic Depth

--- Inferred Rock Boundary

Scale: 1"=50'

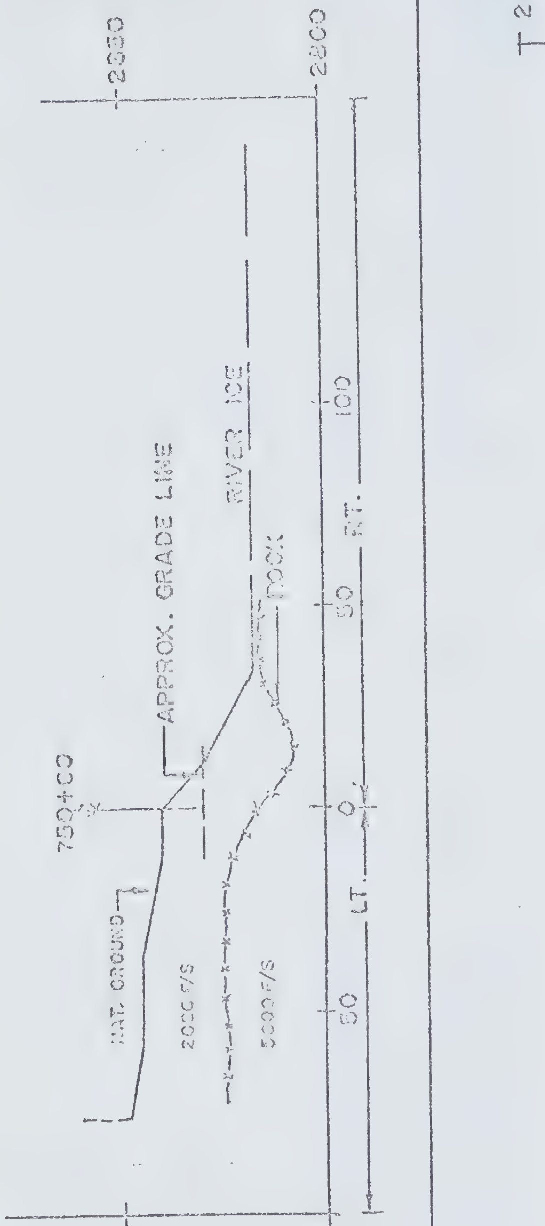
ALBERTA RESOURCES RAILWAY
SECTION 7
SEISMIC PROFILE

CROSSLINE
2283+00

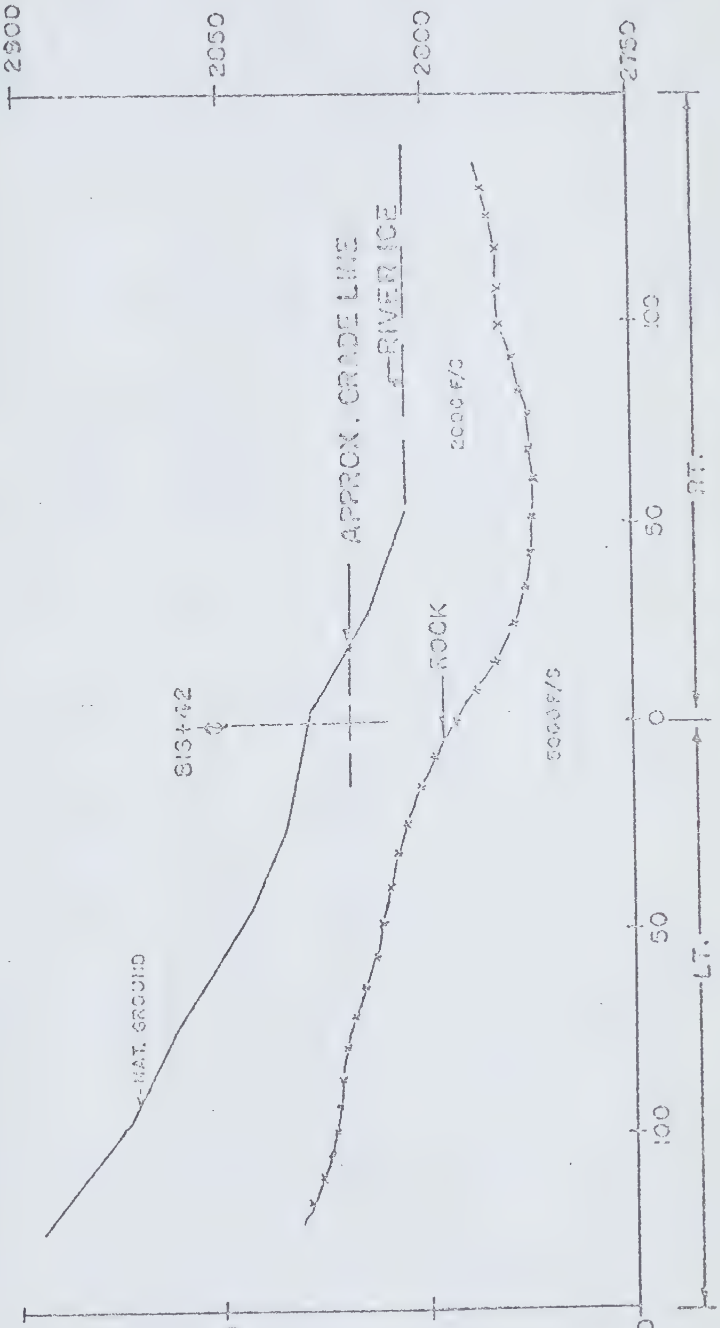
January, 1967
GX-47

FIG.-C.4

Geo-Recon Explorations Ltd.



CROSS-SECTION
SCALE 1" = 50'
MILE 124.3



CROSS-SECTION
SCALE 1" = 50'
MILE 125.5

FIG. - C.5

# TABLE C.2

## ESTIMATION OF SCOUR DEPTHS

| Mile -No. | $F_b$ | q | $d_R$ | $1.7d_R$ | $d_t$ | $d_s$ |
|---|---|---|---|---|---|---|
| 117 - 1 | 7.8 | 139 | 13.7 | 23 | 18 | 5 |
| 2 | 5 | 175 | 18.3 | 31 | 18.5 | 12 |
| 3 | | | | | 15 | |
| 4 | 2 | 207 | 27 | 46 | 22.5 | 23 |
| 121.8- 1 | 5.6 | 224 | 21 | 36 | 23 | 13 |
| 2 | 12 | 303 | 19.7 | 34 | 26 | 8 |
| 3 | 11.3 | 242 | 17.4 | 30 | 23 | 7 |
| 4 | 13.6 | 224 | 15.5 | 26 | 17 | 9 |
| 130 - 1 | 5.5 | 266 | 23.4 | 40 | 25.5 | 15 |
| 2 | 9.4 | 354 | 23.7 | 40 | 27.5 | 12 |
| 3 | 5.6 | 230 | 21.2 | 36 | 24 | 12 |
| 4 | 10.3 | 369 | 23.6 | 40 | 28 | 12 |
| 5 | 7.4 | 278 | 21.8 | 37 | 24 | 13 |
| 118.3- 1 | 7.2 | 189 | 17.1 | 29 | 20 | 9 |
| 2 | 7.3 | 212 | 18.3 | 31 | 21 | 10 |
| 3 | 7.7 | 239 | 19.5 | 33 | 22 | 11 |
| 4 | 7.7 | 250 | 20.2 | 34 | 22 | 12 |
| 136 - 1 | 8.4 | 135 | 13 | 22 | 18 | 2 |
| 2 | 6.3 | 147 | 15 | 25 | 18 | 3 |
| 3 | 5.5 | 129 | 14.5 | 25 | 19 | 6 |
| 4 | 7.3 | 129 | 13.2 | 22 | 16 | 6 |
| 5 | 6.2 | 170 | 16.7 | 28 | 24 | 4 |
| 6 | 5.0 | 257 | 13.2 | 22 | 19 | 3 |
| 144 - 1 | 6.3 | 189 | 17.8 | 30 | 21 | 9 |
| 2 | 6.0 | 174 | 17.2 | 29 | 20 | 9 |
| 3 | 7.0 | 236 | 20 | 34 | 26 | 8 |
| 4 | 8.3 | 189 | 21 | 36 | 20 | 16 |
| 5 | 3.2 | 174 | 21 | 36 | 25 | 11 |
| 6 | 8.2 | 293 | 22 | 37 | 26 | 11 |
| 7 | 5.5 | 212 | 20 | 34 | 22 | 12 |
| 155 - 1 | 4.3 | 274 | 26 | 44 | 33 | 11 |
| 2 | 11 | 320 | 21 | 35 | 25 | 10 |
| 161.5- 1 | 14 | 303 | 19 | 32 | 22 | 10 |
| 2 | 6.3 | 172 | 17 | 28 | 21 | 7 |
| 3 | 9.5 | 250 | 19 | 32 | 27 | 5 |
| 4 | 21.0 | 274 | 15 | 25 | 23 | 2 |
| 5 | 8.5 | 230 | 18 | 30 | 22 | 8 |
| 169 - 1 | 3.4 | 236 | 25 | 42 | 29 | 13 |
| 2 | 9.3 | 227 | 19 | 32 | 21 | 11 |
| 3 | 5.6 | 212 | 20 | 33 | 24 | 9 |
| 4 | 4.4 | 212 | 22 | 37 | 26 | 11 |

durability over the long term. Could the bedrock material break down due to weathering processes and in zones where high intensity flows continuously expose the bed to direct attack, particularly in reaches where the natural channel has been artificially constricted by the A.R.R. As is discussed in Appendix D, this question is important in the consideration of bank armouring designs.

C.4 Profile; Figure C.6 shows four profiles; (1) base of rail, (2) water surface surveyed in November, 1972, (3) bed (thalweg) profile surveyed, and (4) approximate water surface profile of 1972 flood peak. The last three profiles had to be extrapolated between surveyed reaches so only provide an approximate set of information for most of the river length being studied.

The flood-profile does indicate that the constructed grade might have been overtopped at numerous locations, as for example in the reaches:

- Mile 122.5 to 125
- Mile 126.5 to 128.2
- Mile 144
- Mile 147.5 to 148.5
- Mile 156.6 to 157.7
- Mile 158.7 to 160.5
- Mile 165.5 to 168

There were many reaches where the water surface was likely near base-of-rail level and at times it is difficult to establish in the field whether the embankment was eroded out by local inflow overtopping the embankment because of insufficient culvert capacity or whether the Smoky River itself went over the tracks.

C.5 Modes of Failure; a field reconnaissance of the many damaged A.R.R. reaches along the Smoky River provided an opportunity to determine

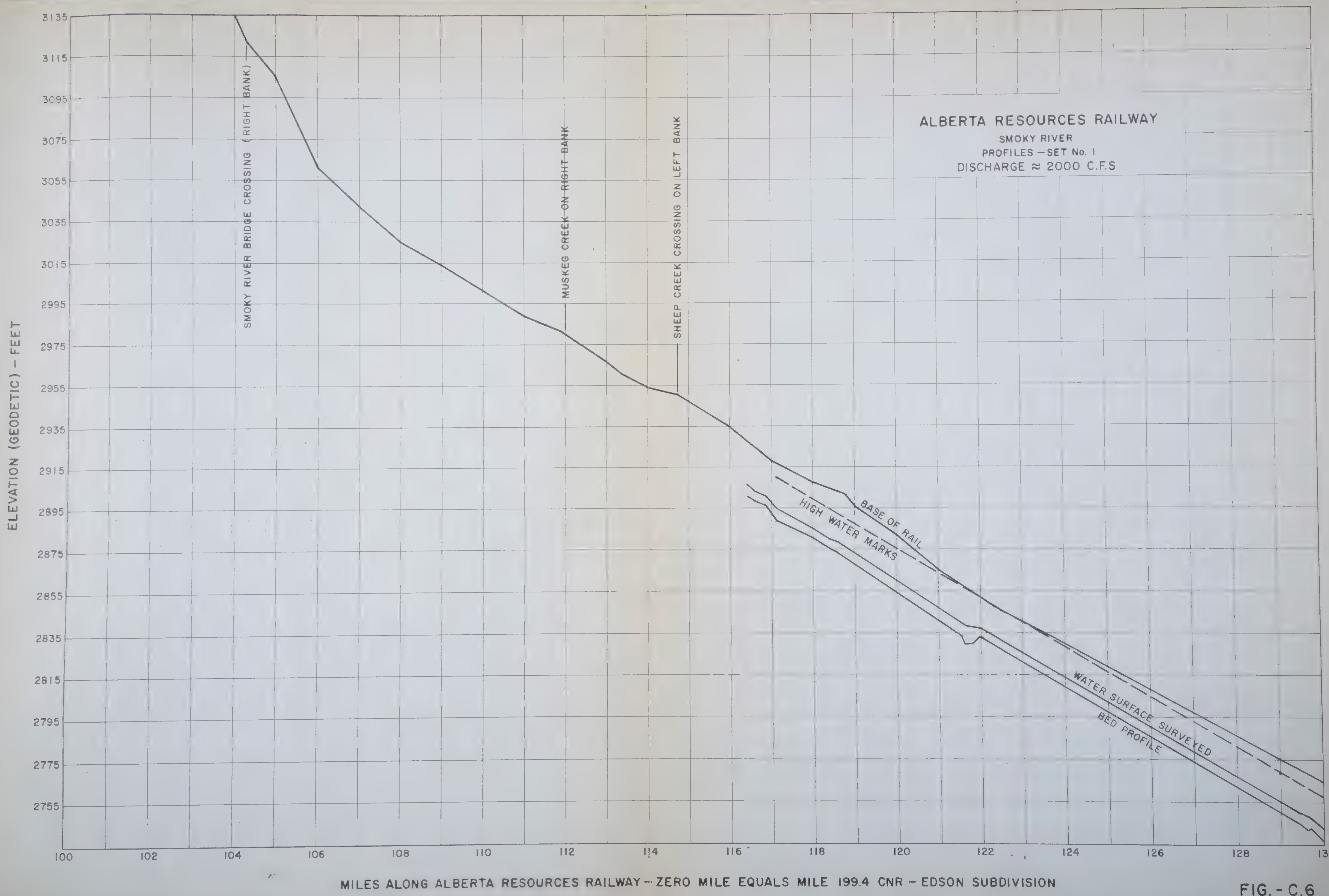

ALBERTA RESOURCES RAILWAY
SMOKY RIVER
PROFILES – SET No. 1
DISCHARGE ≈ 2000 C.F.S

FIG. - C.6

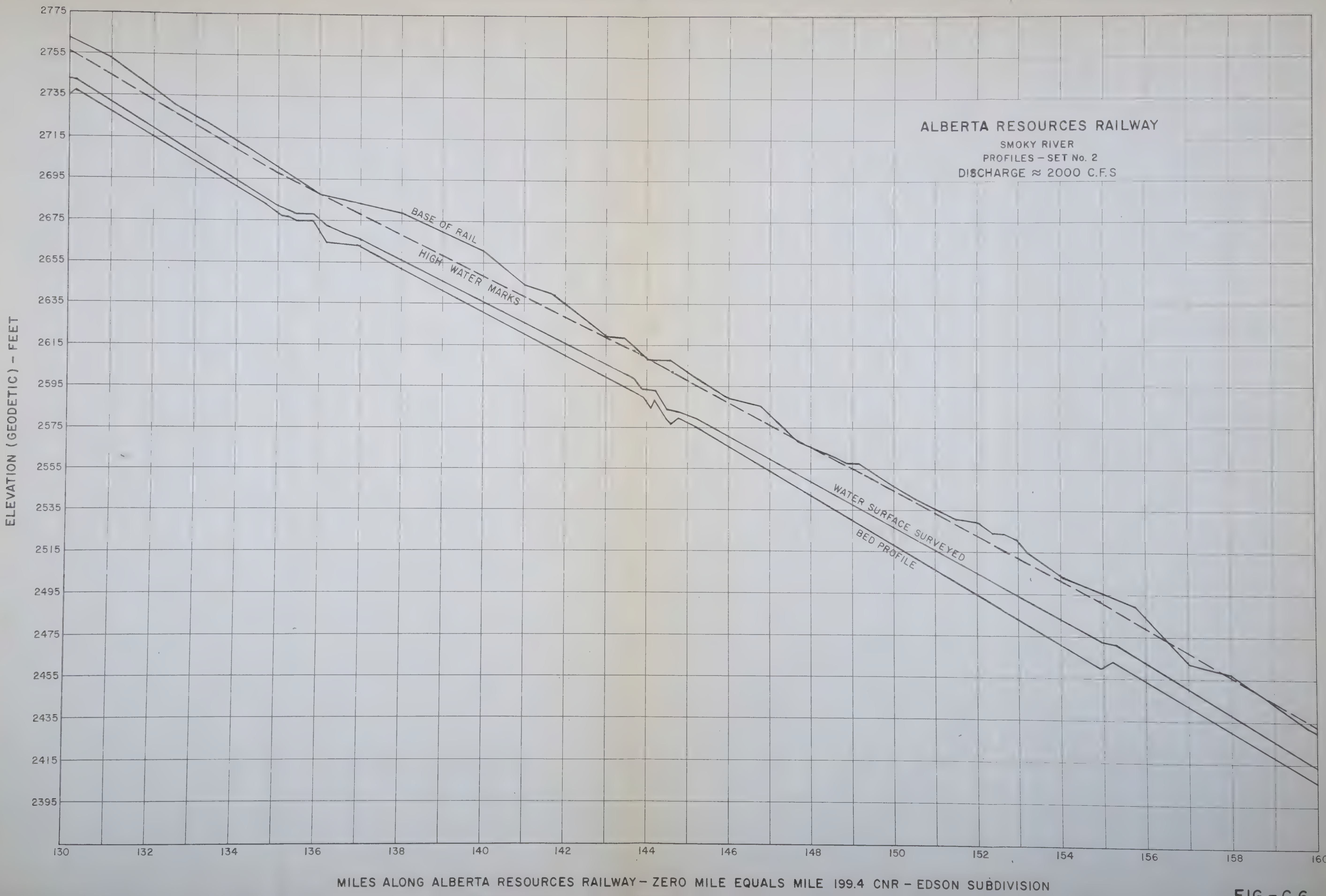

ALBERTA RESOURCES RAILWAY
SMOKY RIVER
PROFILES – SET No. 2
DISCHARGE ≈ 2000 C.F.S
BASE OF RAIL
HIGH WATER MARKS
WATER SURFACE SURVEYED
BED PROFILE
ELEVATION (GEODETIC) – FEET
2775
2755
2735
2715
2695
2675
2655
2635
2615
2595
2575
2555
2535
2515
2495
2475
2455
2435
2415
2395
130
132
134
136
138
140
142
144
146
148
150
152
154
156
158
160
MILES ALONG ALBERTA RESOURCES RAILWAY – ZERO MILE EQUALS MILE 199.4 CNR – EDSON SUBDIVISION

FIG.- C.6

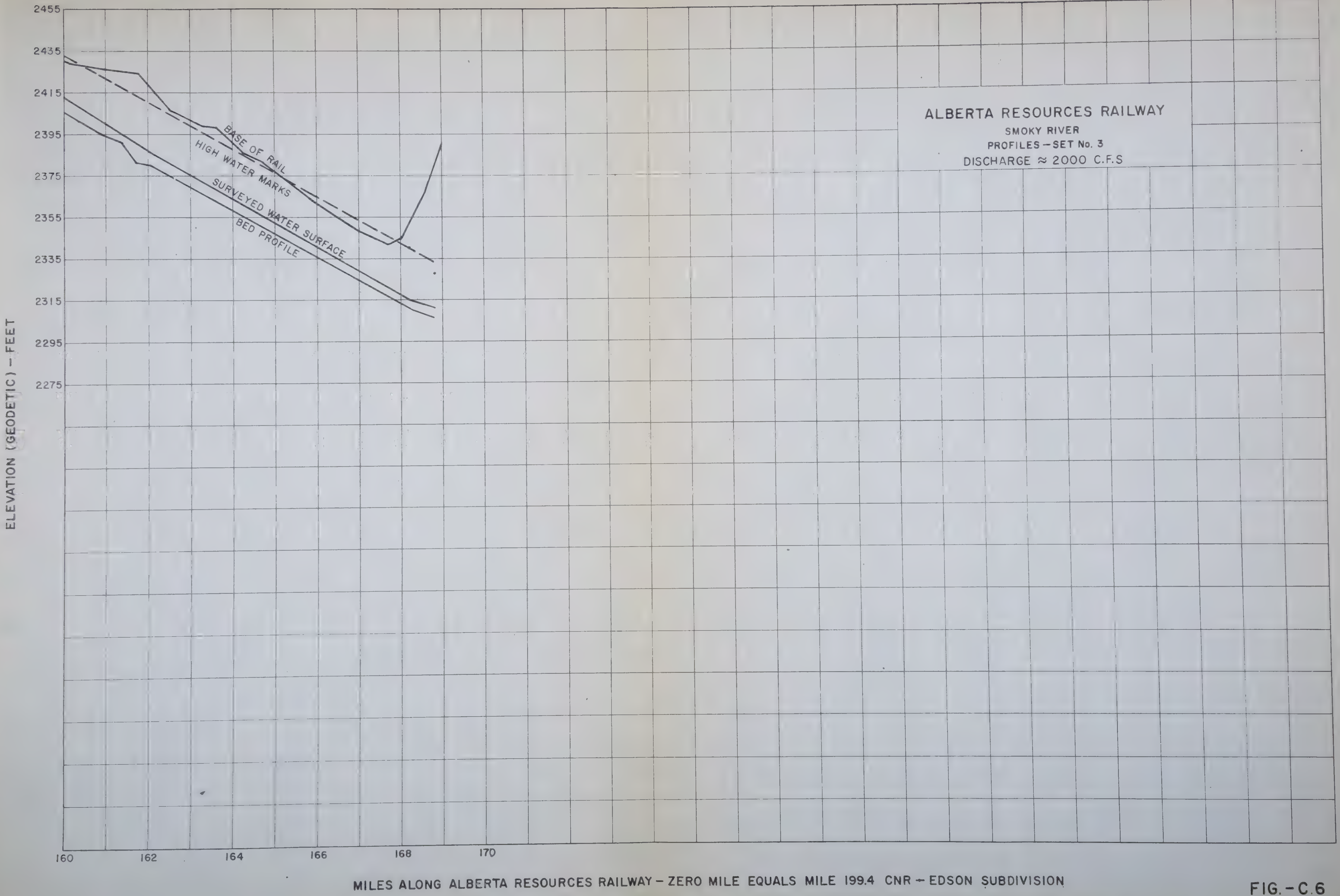

ALBERTA RESOURCES RAILWAY
SMOKY RIVER
PROFILES – SET No. 3
DISCHARGE ≈ 2000 C.F.S
BASE OF RAIL
HIGH WATER MARKS
SURVEYED WATER SURFACE
BED PROFILE
ELEVATION (GEODETIC) – FEET
2455
2435
2415
2395
2375
2355
2335
2315
2295
2275
160
162
164
166
168
170
MILES ALONG ALBERTA RESOURCES RAILWAY – ZERO MILE EQUALS MILE 199.4 CNR – EDSON SUBDIVISION

FIG. – C.6

what were some of the reasons the damage did occur, regardless of any consideration of the question of whether or not the frequency of the 1972 flood was beyond a practical design level.

(a) Rip rap - the stone provided for armouring was in the writer's opinion of inadequate durability. The primary material used was sandstone which had an obvious wide range durability. Some of the stone could be broken apart merely by kicking it (see photograph F.7) while other sandstone rocks displayed at least a visual impression of being hard and dense (see photograph F.3). However, even these latter rocks showed signs of weathering (cracks, flaking) upon closer examination.

- shape of stone was not always acceptable. Some of the stone provided was extremely large in two dimensions (up to eight feet) but the third dimension was relatively small so that the stone was essentially flat (see photograph F.2). Unless this type of material is laid down carefully in an unexposed position it can be lifted out of place by differential pressures between the surface of the rocks and the surface of the embankment.
- gradation of the stone used was too uniform. Without any "chinking" material or intermediate sizes to close off interstices, the underlying embankment material was sucked up and the rock undermined. Photograph F.2 shows an example of where even though the stone used was very big, the underlying material became exposed. If these large, uniform sizes had to be used then a filter blanket should have been first placed on the embankment slope. Photograph

F.4 shows why it might have been possible for the embankment material to be pulled up through the voids of the rip rap. Note in this photograph the very fine material used for the embankment, which would have easily been pulled out under conditions of highly turbulent flow over the roughly surfaced rip-rapped bank.

(b) Apron - in some cases it appeared as if a scour hole along the toe of the embankment caused the overlying rip rap material to slip down, and in the process expose the embankment material. The use of a small apron would have prevented this from occurring.

(c) Insufficient Armouring

- it looked as if large amounts of rock were at times placed along the bottom-third of the embankment with little above this. Flow proceeded to erode away the embankment material above the rip rap and in some cases worked back to the tracks. The result was an eroded ledge between the track and a line of rip rap material, as shown in photograph F.4.

(d) Overtopping of Embankment

- local inflow could not be handled by some of the culverts through the embankment. Gravel would have likely filled up the culverts, partially plugging them off (photograph F.1) so that water ponding up behind the embankment would either overtop the track or run along the embankment until it found other openings into the river.

Also it was obvious from the alignment of some debris that water from the Smoky River did overtop the embankment at

numerous places and this is borne out in the profiles of Figure C.6.

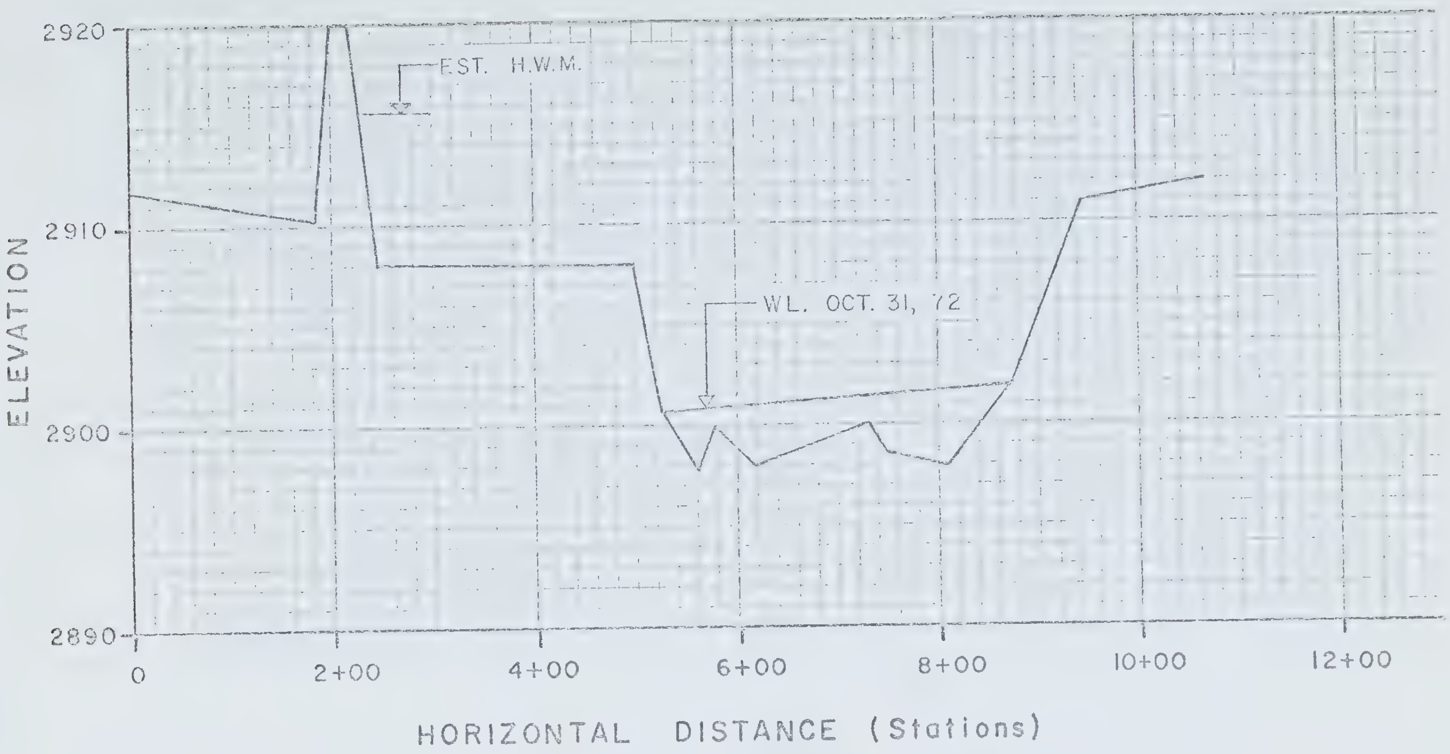
C.6 Channel Regime; the Smoky River is a gravel bed channel with bed material sizes ranging up to eighteen inches. Where there is a recently active bed bar the mean size of gravel would be about five inches. There appeared to be a few reaches where alluvium made up the banks (terraces, point bars) and there appeared to be negligible deposits of till visible along the river. Bank erosion processes below Mile 115 did not seem to be much of a supplier of the gravel bed material and it is likely that the majority of gravel is transported from eroding glacial deposits in the mountains above Grande Cache, with smaller amounts coming from Sheep Creek and the Muskeg River.

The adjacent valley walls are composed of weathered bedrock which show numerous active slump areas. The river has cut into this bedrock at some locations and in the process precipitated a slump of the bank into the river channel. This situation was one reason why it was decided to move the embankment into the channel and away from these unstable slopes.

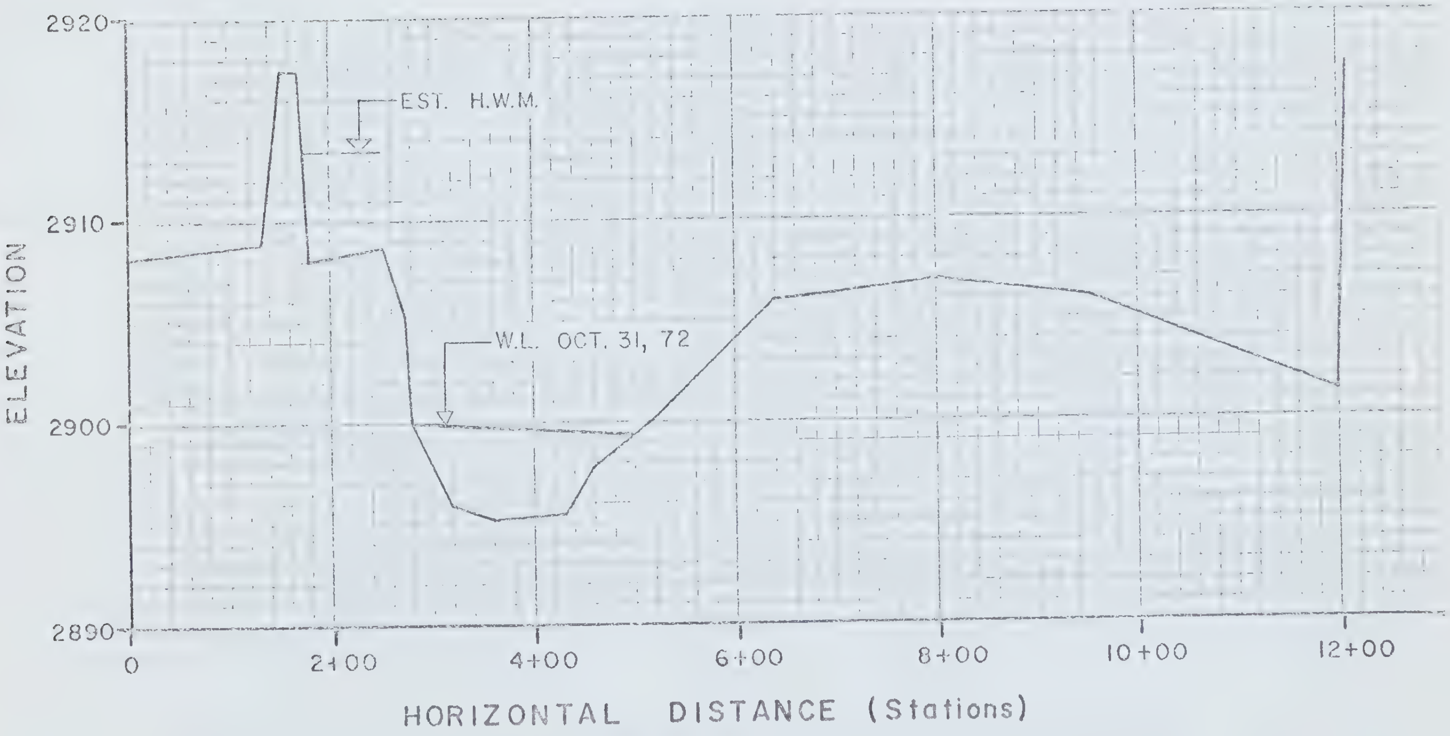
The Smoky River does meander within the narrow valley but the pattern is quite irregular so that the channel alignment in a lot of cases is imposed by bedrock outcrops.

FIGURE C.1

Cross-Sections



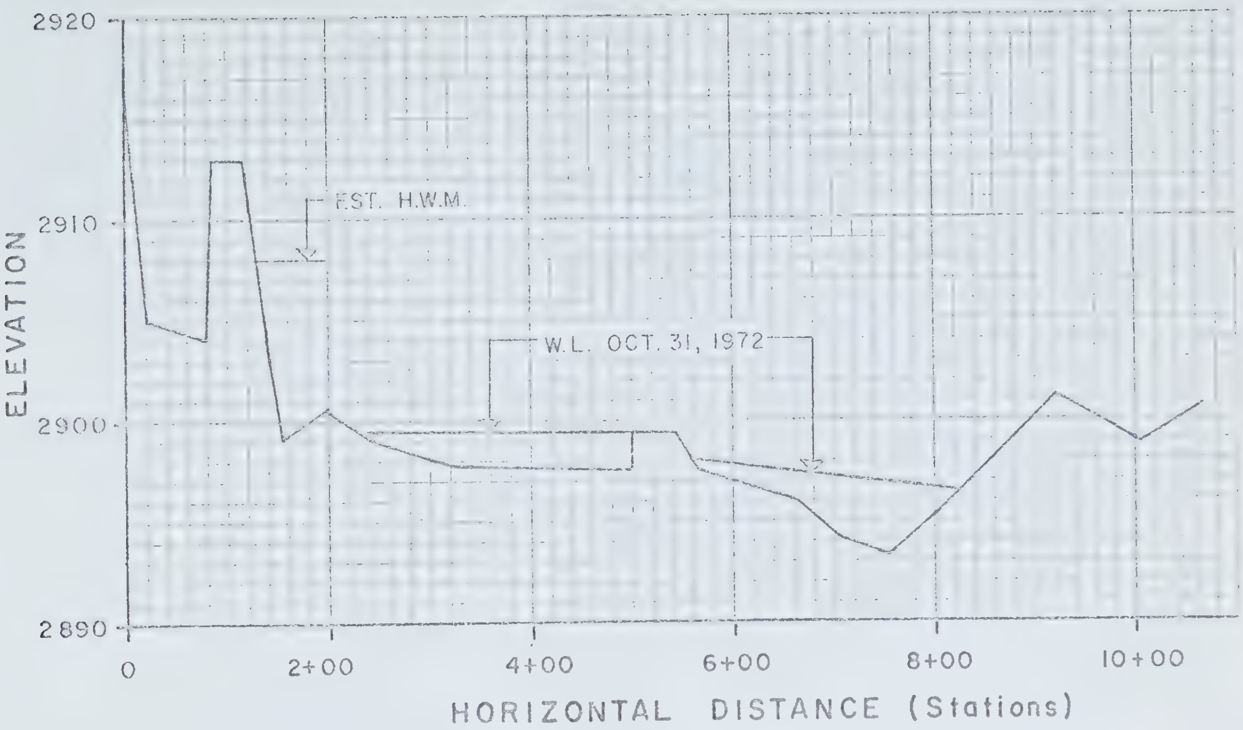
CROSS-SECTION 117-1



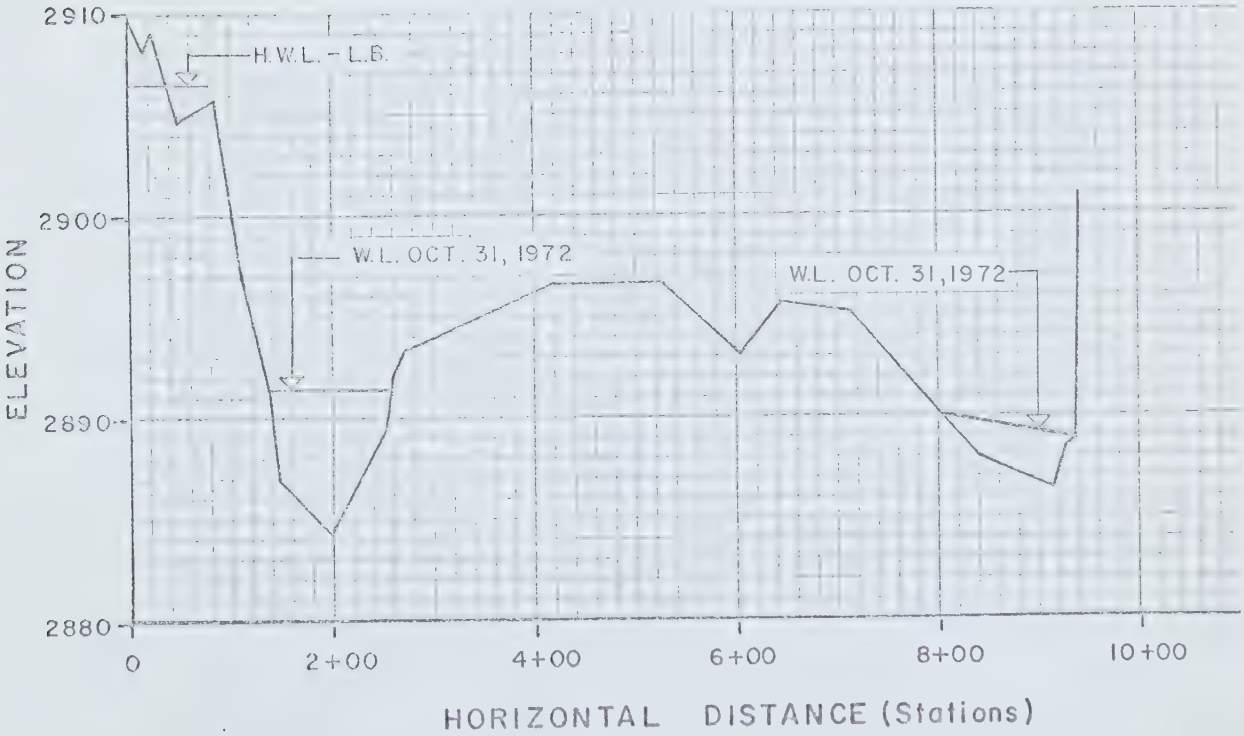
CROSS-SECTION 117-2

# SMOKY RIVER

FOR GEODETIC ELEVATION ADD 3.5 FEET



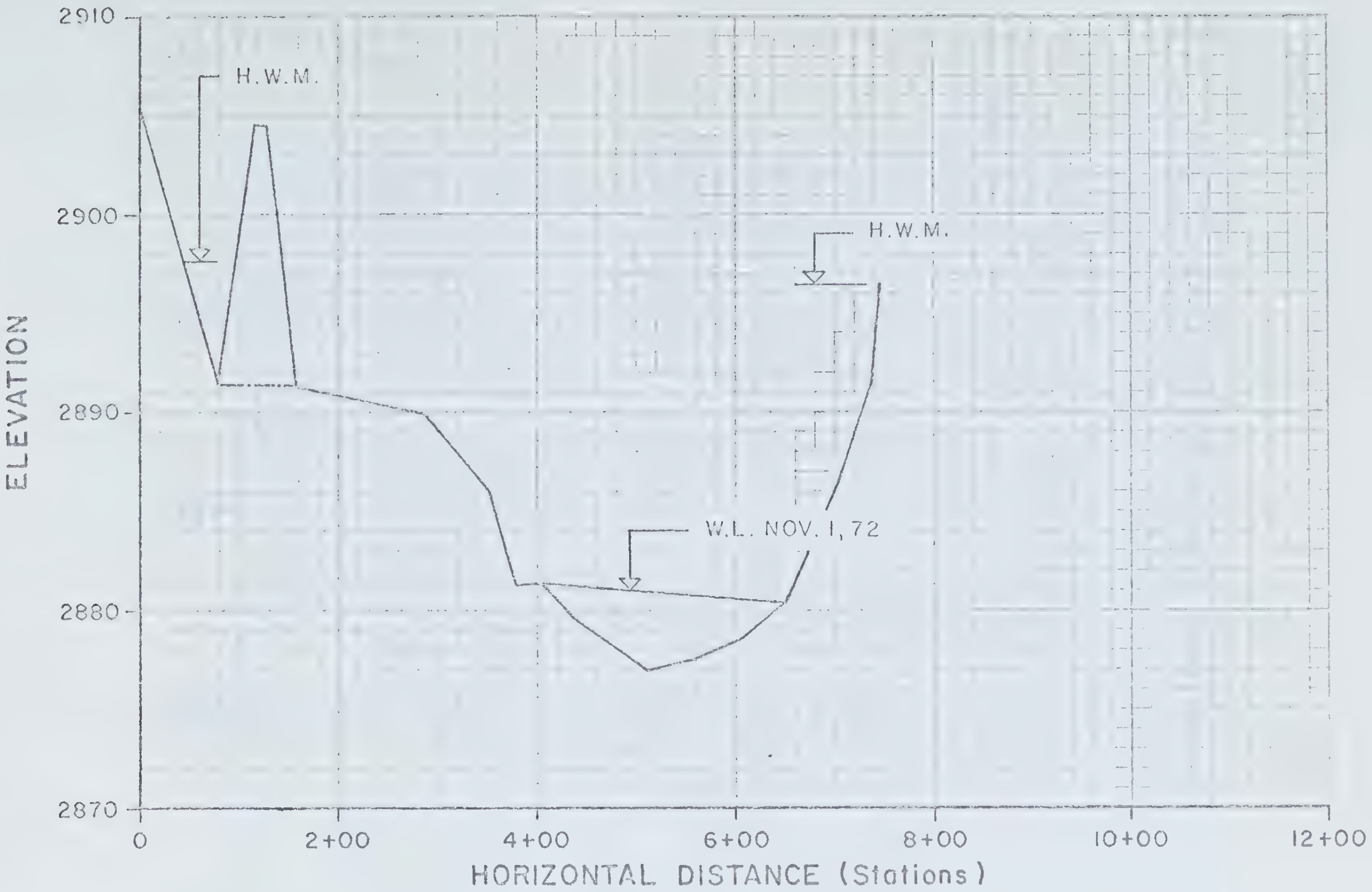
CROSS-SECTIONS 117-3



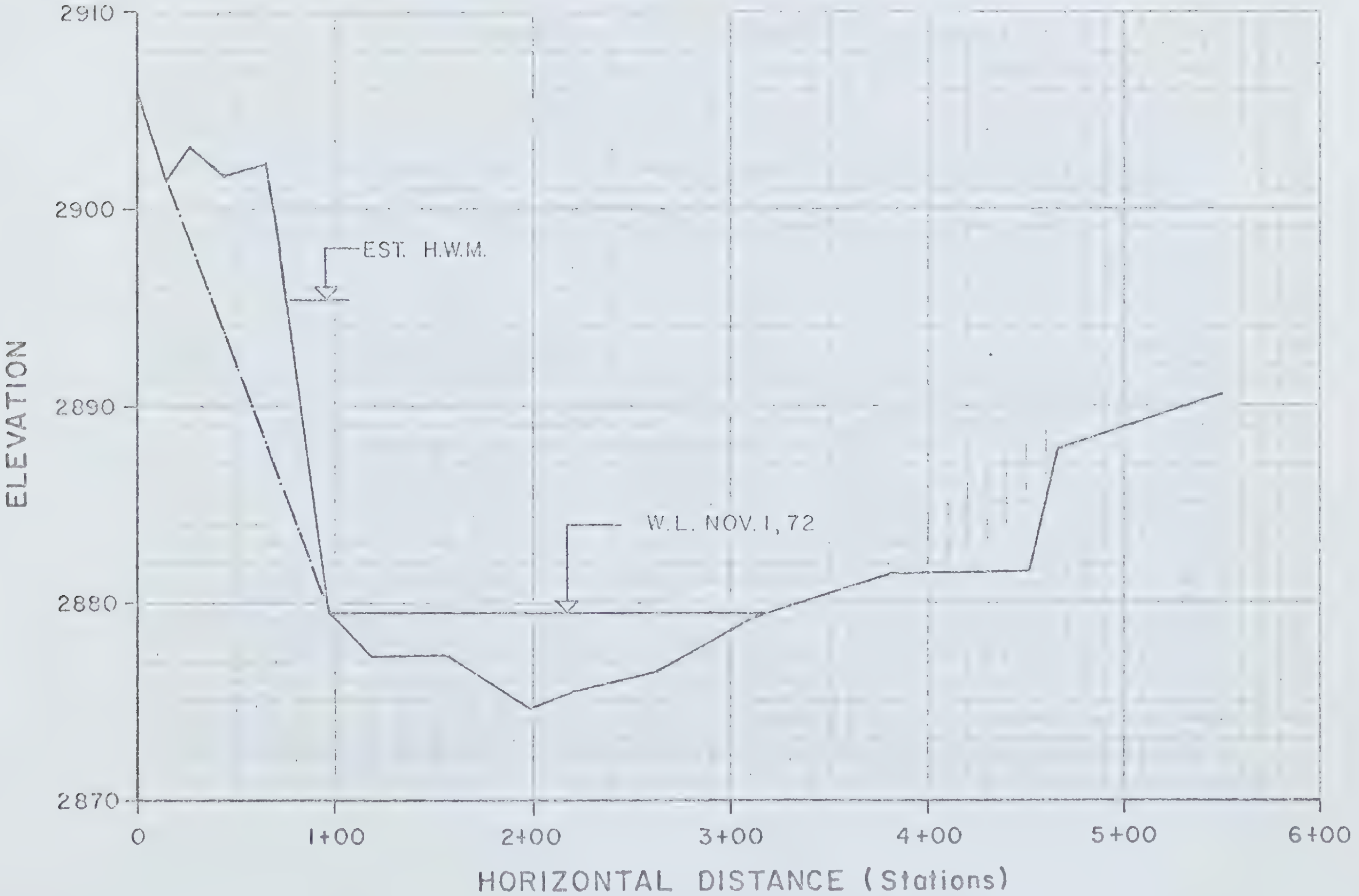
CROSS-SECTION 117-4

FOR GEODETIC ELEVATION ADD 3.5 FEET

## SMOKY RIVER



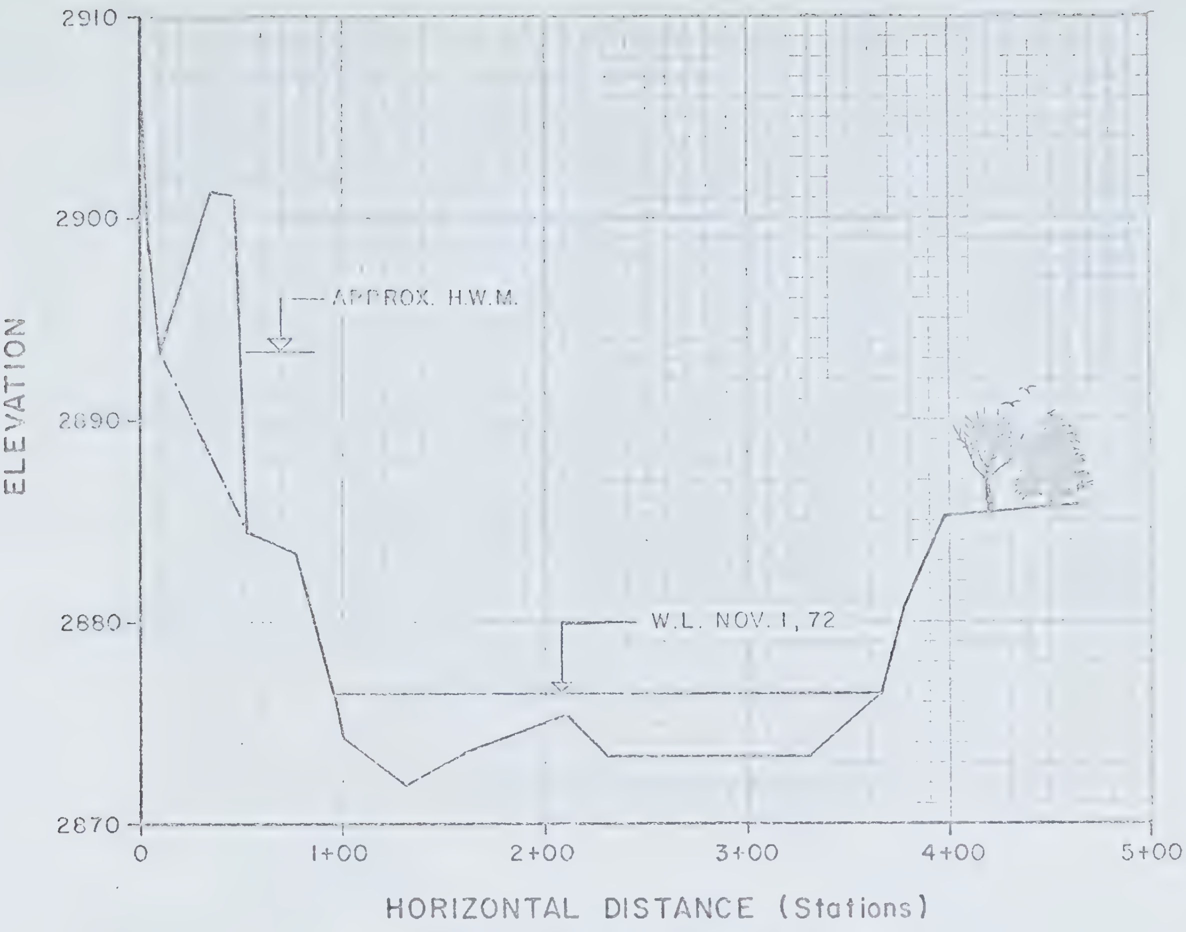
CROSS-SECTION 118.3-1



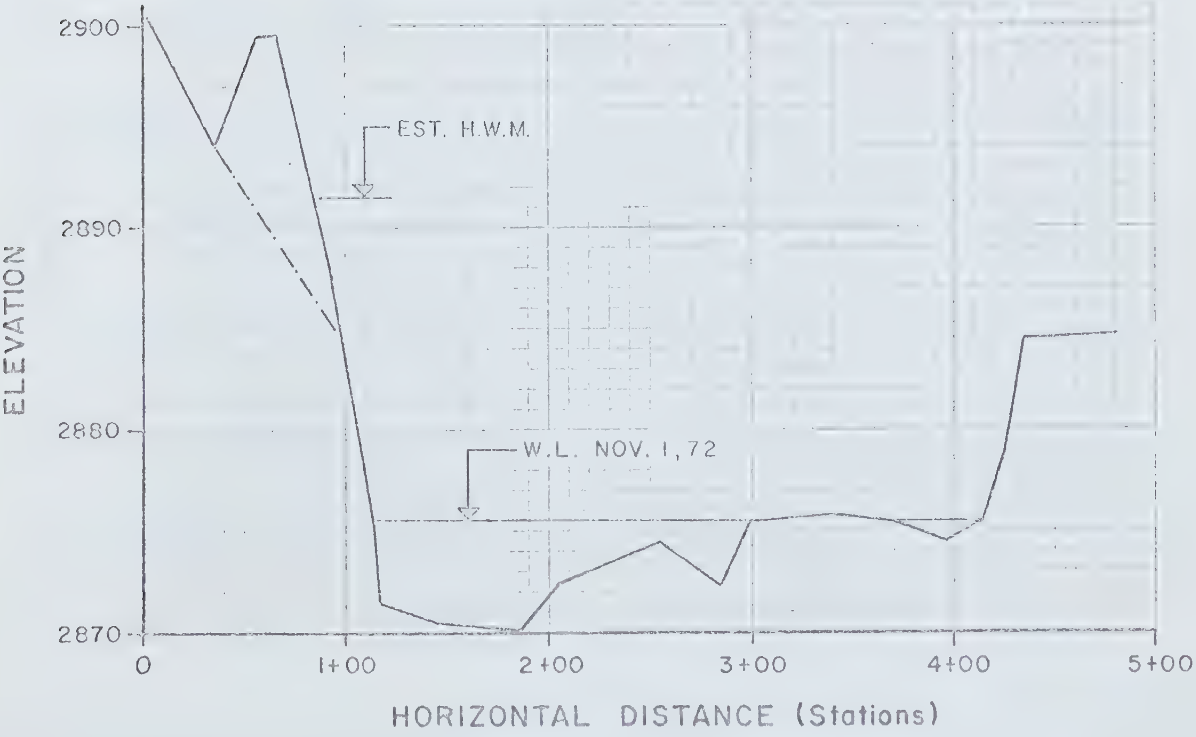
CROSS-SECTION 118.3-2

—·— ESTIMATED ORIGINAL CHANNEL
FOR GEODETIC ELEVATION ADD 3.5 FEET

# SMOKY RIVER



CROSS-SECTION 118.3 – 3

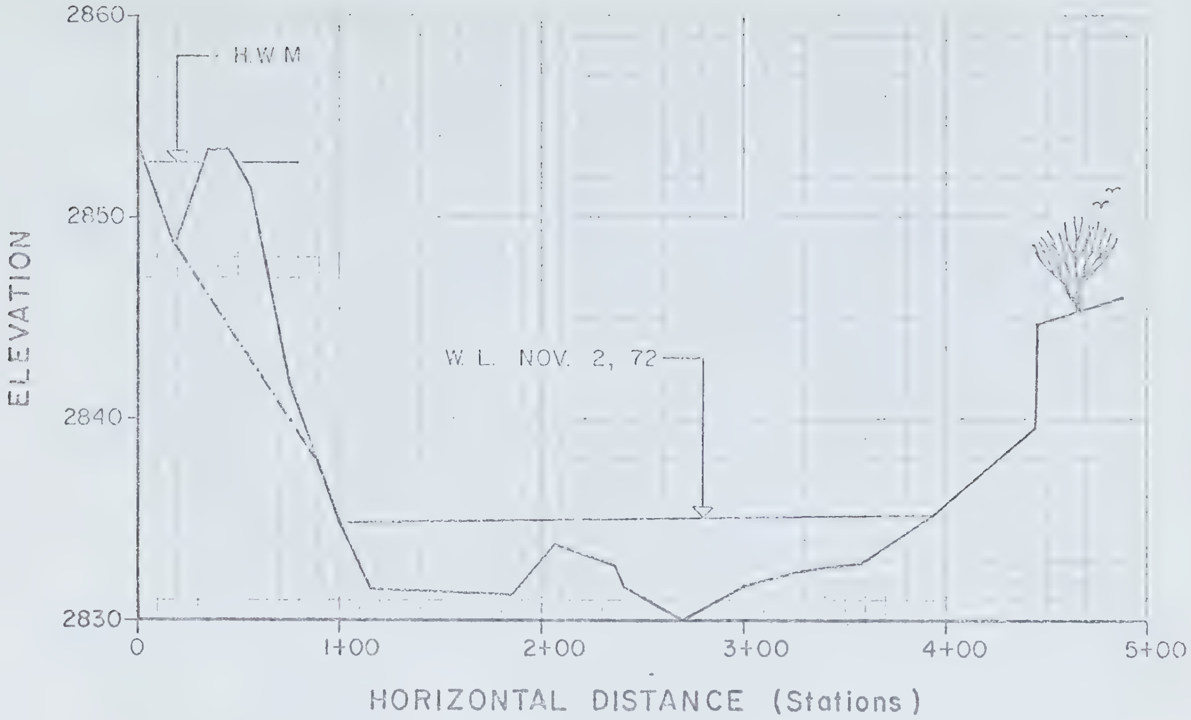


CROSS-SECTION 118.3 – 4

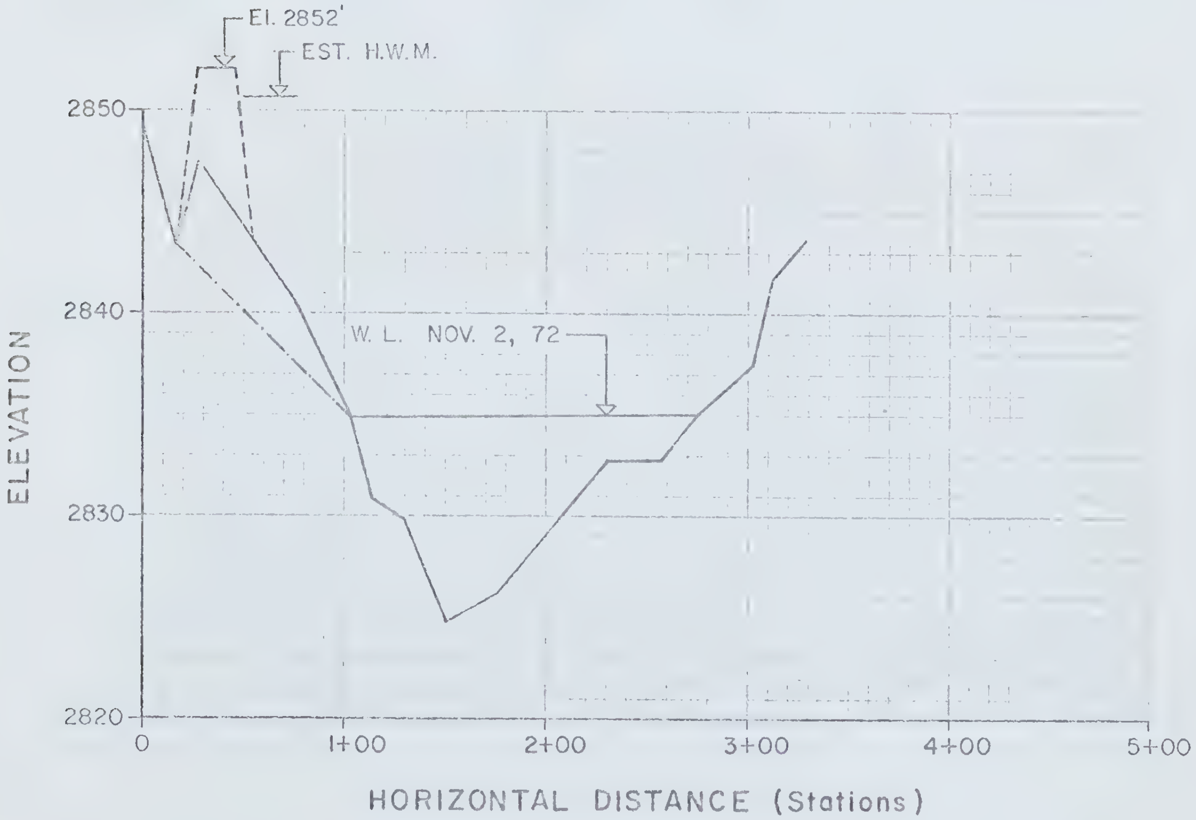
-·- ESTIMATED ORIGINAL CHANNEL

FOR GEODETIC ELEVATION ADD 3.5 FEET

# SMOKY RIVER



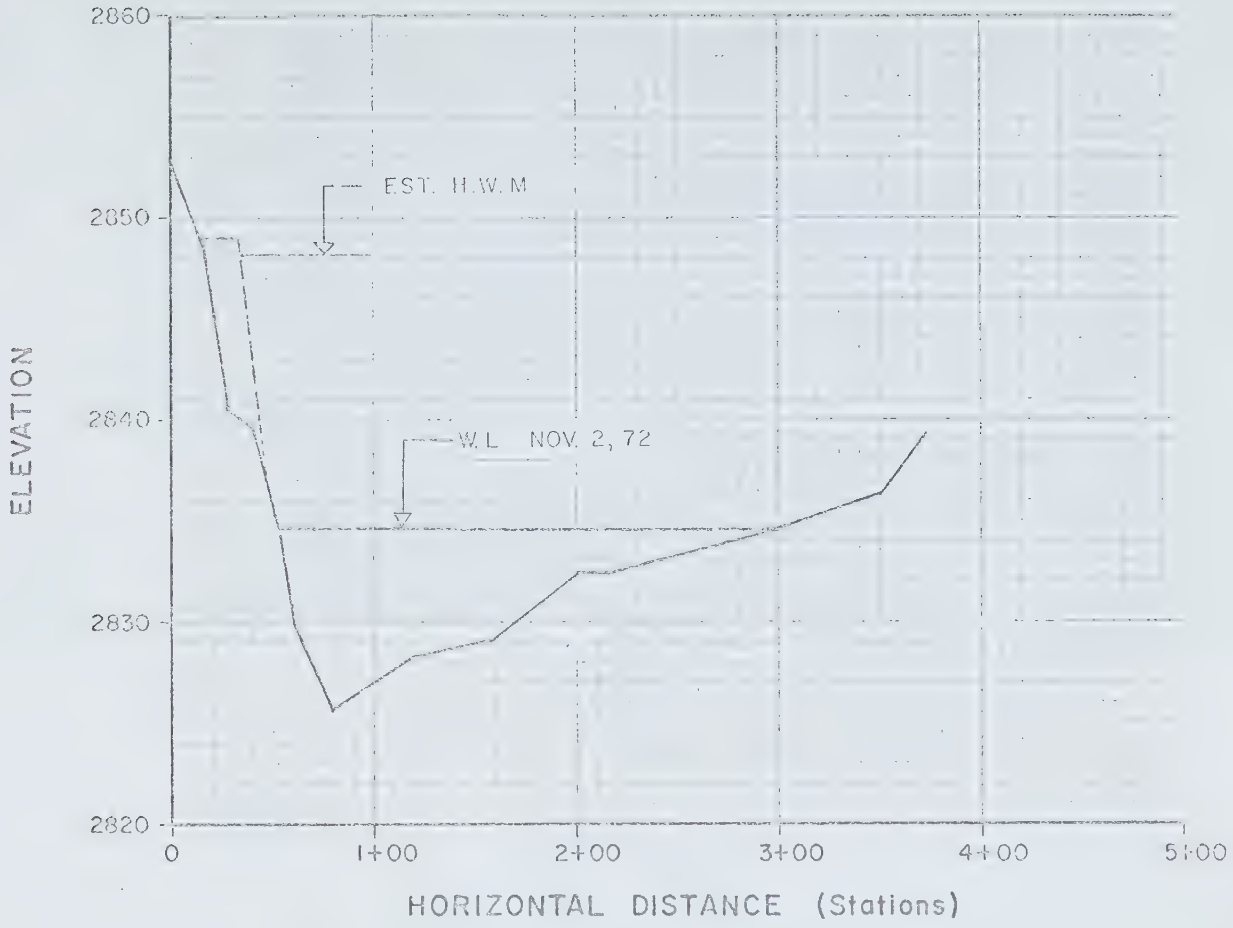
CROSS – SECTION 121.8-1



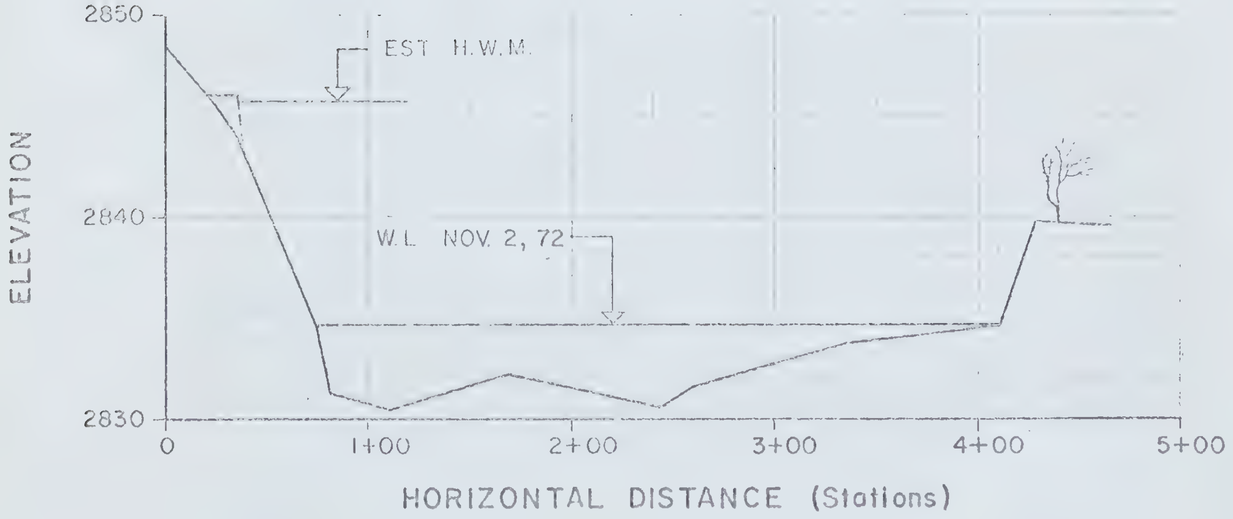
CROSS – SECTION 121.8-2

– – – ESTIMATED ORIGINAL EMBANKMENT
–·–·– ESTIMATED ORIGINAL CHANNEL
FOR GEODETIC ELEVATION ADD 3.5 FEET

## SMOKY RIVER



CROSS-SECTION 121.8-3

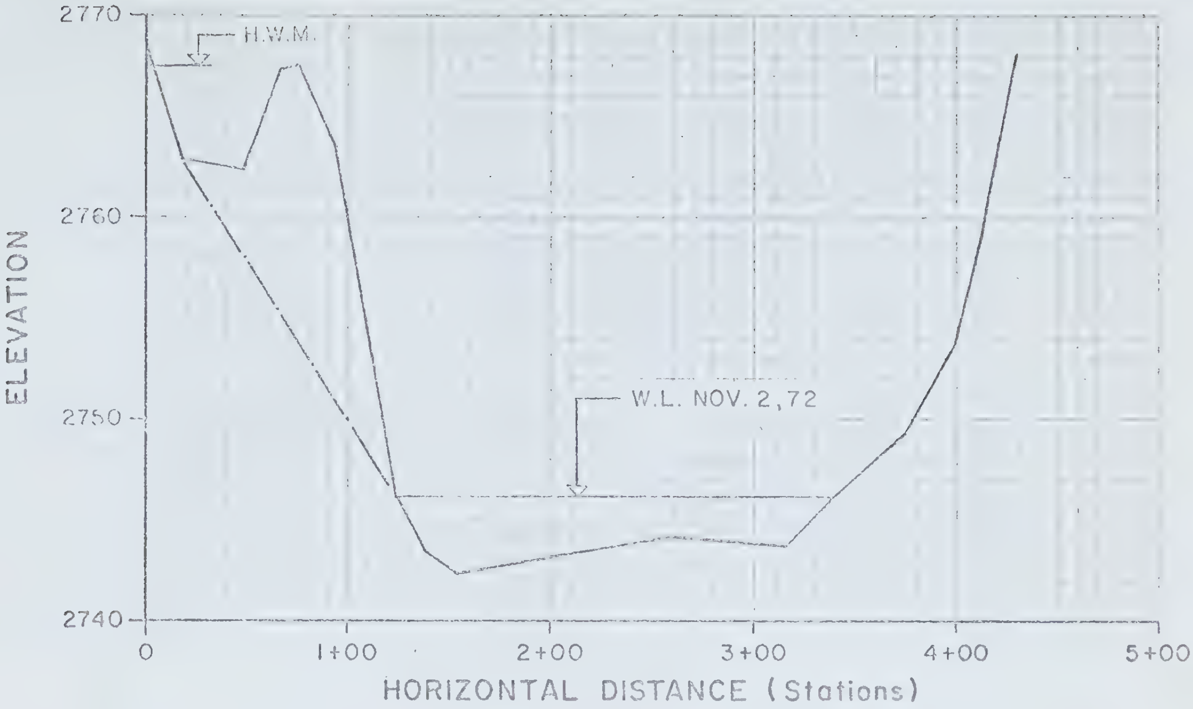


CROSS-SECTION 121.8-4

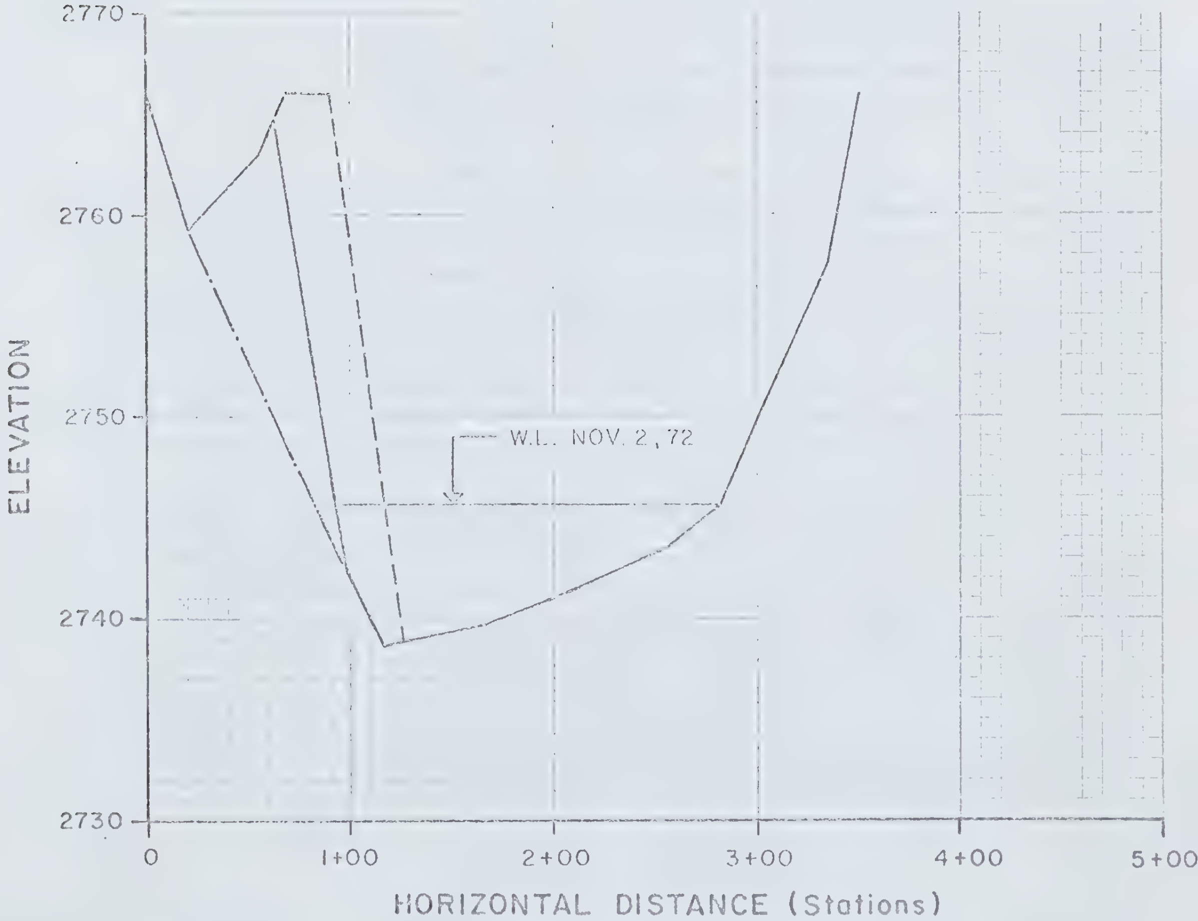
--- ESTIMATED ORIGINAL EMBANKMENT

FOR GEODETIC ELEVATION ADD 3.5 FEET

SMOKY RIVER



CROSS-SECTION 130-1

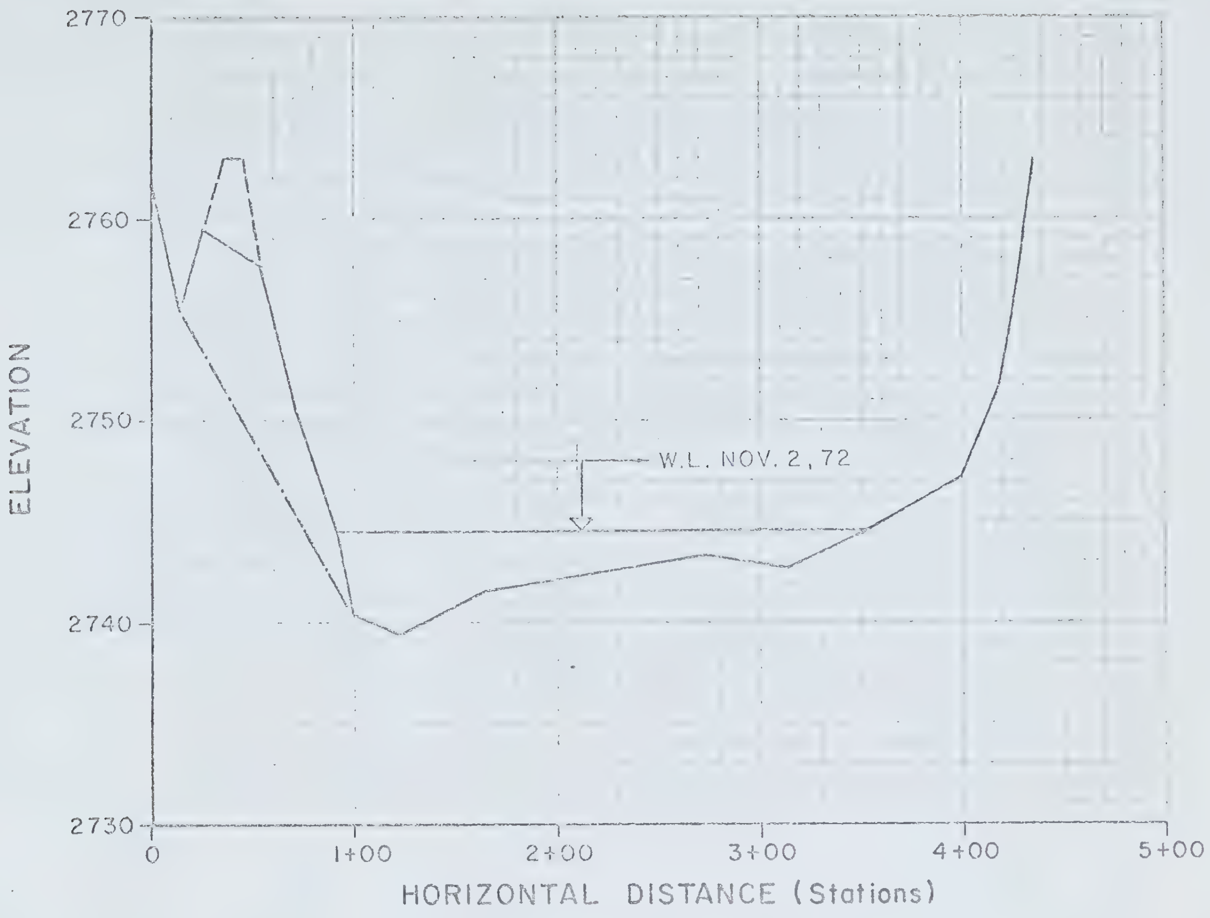


- - - - ESTIMATED ORIGINAL EMBANKMENT
—·—·— ESTIMATED ORIGINAL CHANNEL

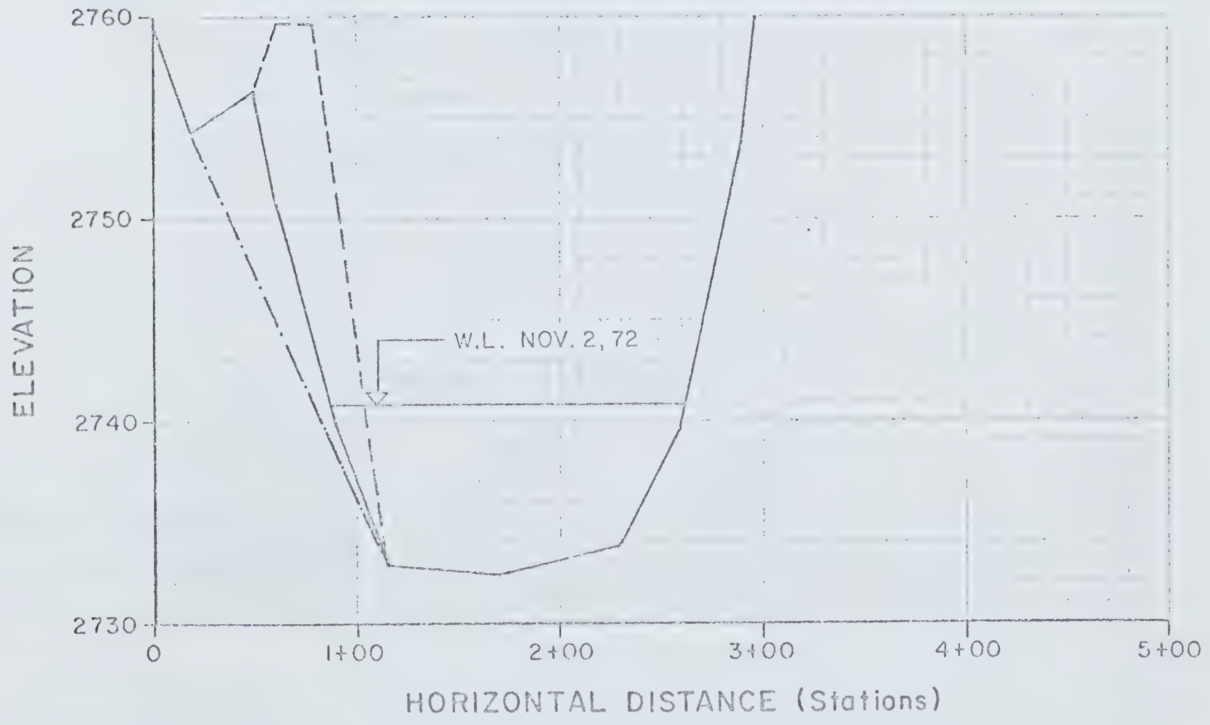
CROSS-SECTION 130-2

FOR GEODETIC ELEVATION ADD 3.5 FEET

# SMOKY RIVER



CROSS-SECTION 130-3

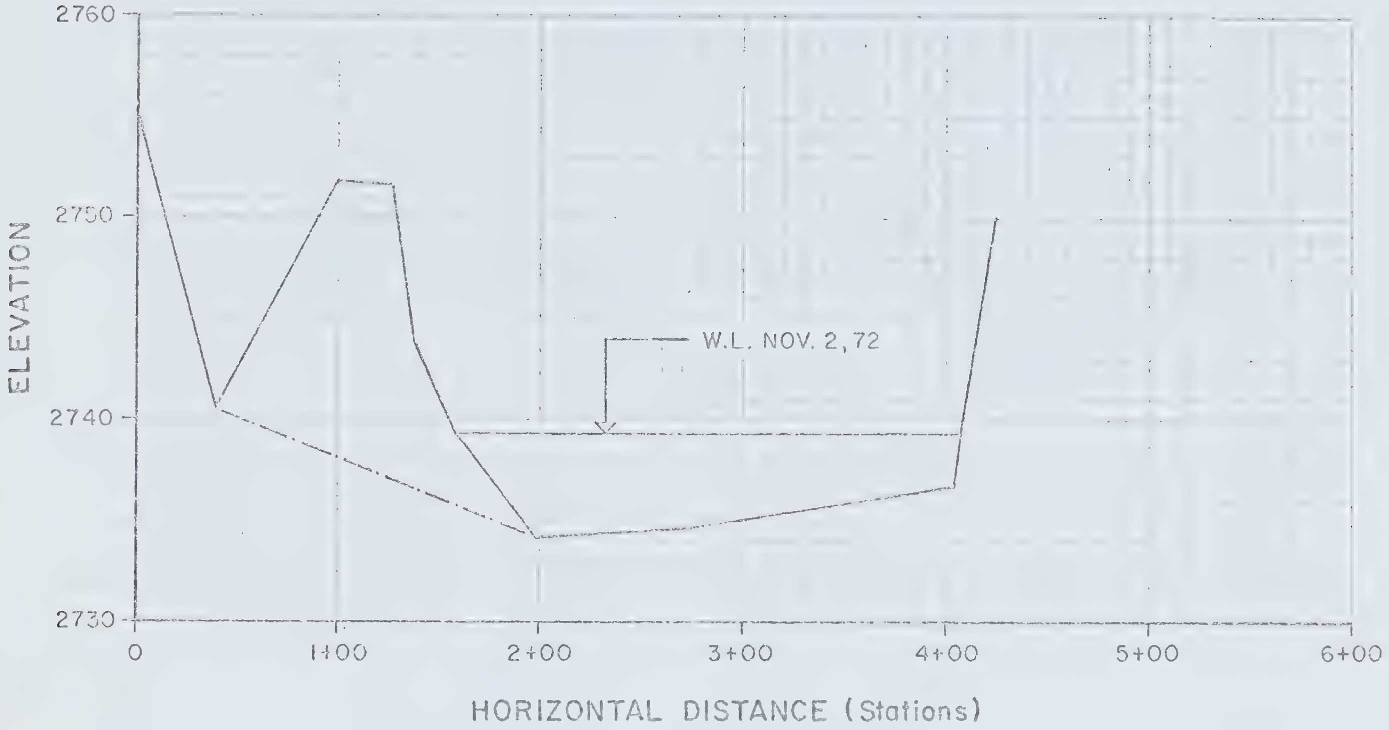


CROSS-SECTION 130-4

– – – ESTIMATED ORIGINAL EMBANKMENT
–·–·– ESTIMATED ORIGINAL CHANNEL

FOR GEODETIC ELEVATION ADD 3.5 FEET

## SMOKY RIVER

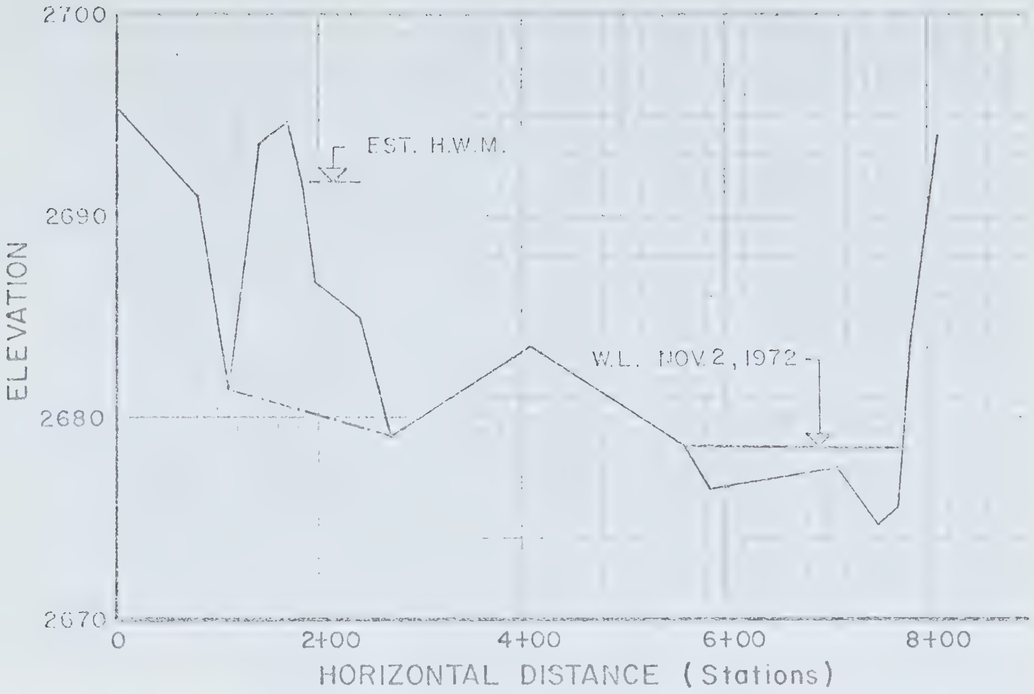


CROSS-SECTION 130-5

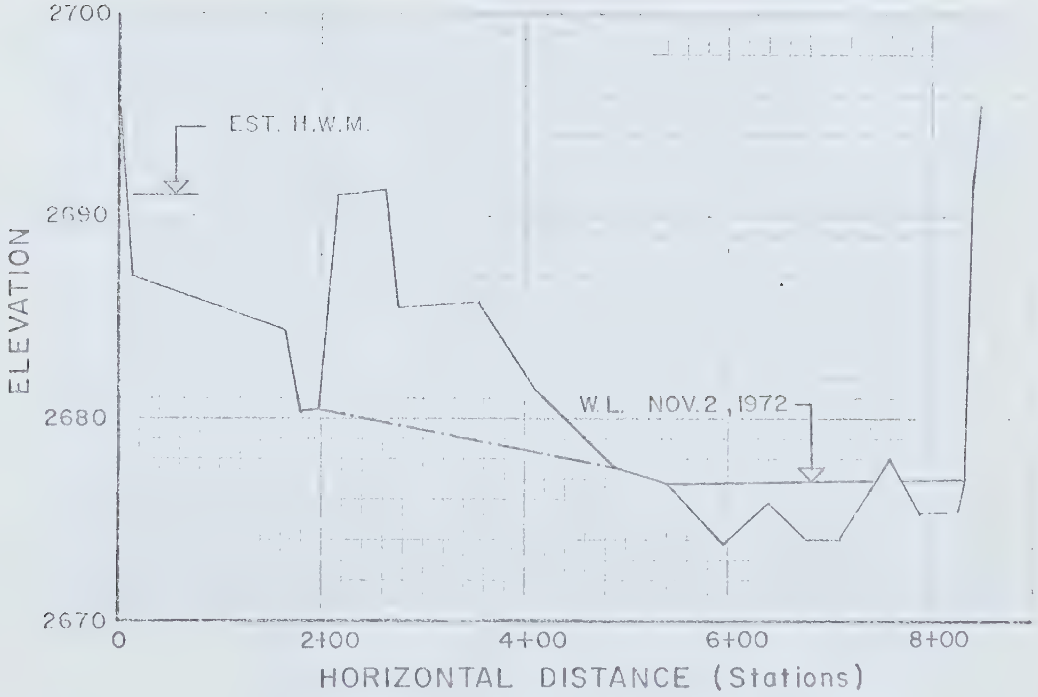
# SMOKY RIVER

—·— ESTIMATED ORIGINAL CHANNEL

FOR GEODETIC ELEVATION ADD 3.5 FEET



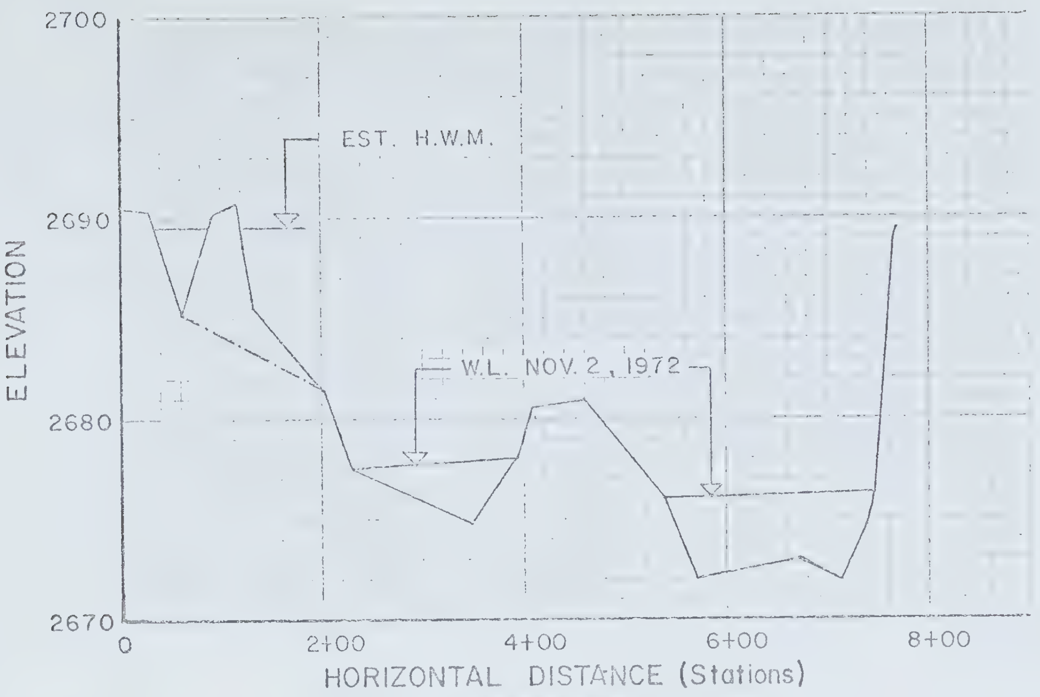
CROSS-SECTION 136-1



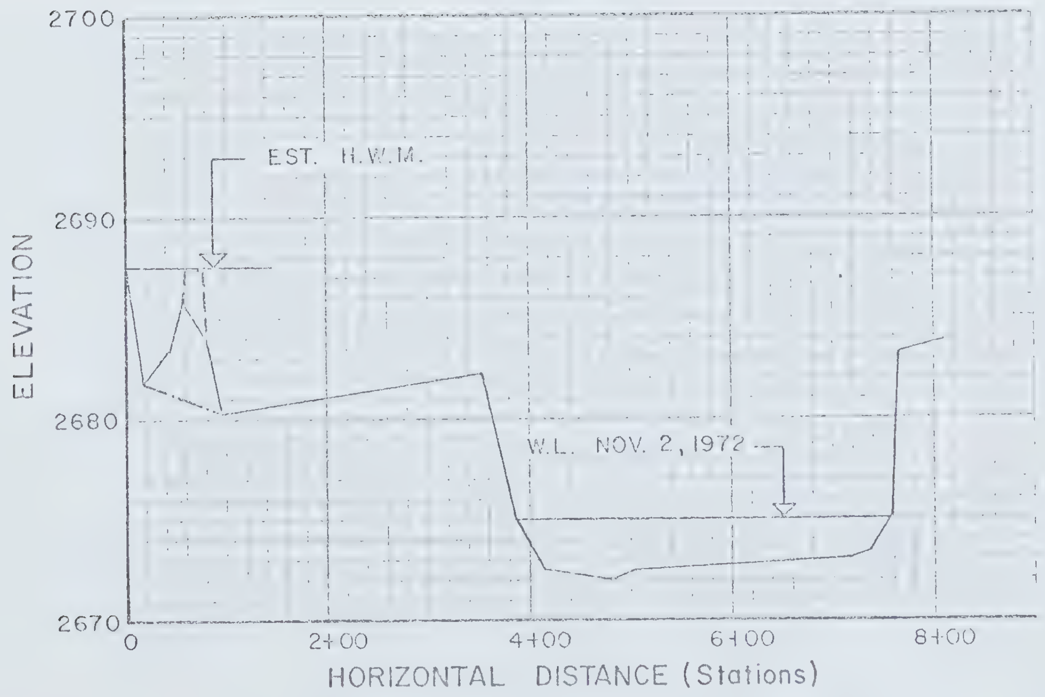
CROSS-SECTION 136-2

— ESTIMATED ORIGINAL CHANNEL
FOR GEODETIC ELEVATION ADD 3.5 FEET

## SMOKY RIVER



CROSS-SECTION 136-3



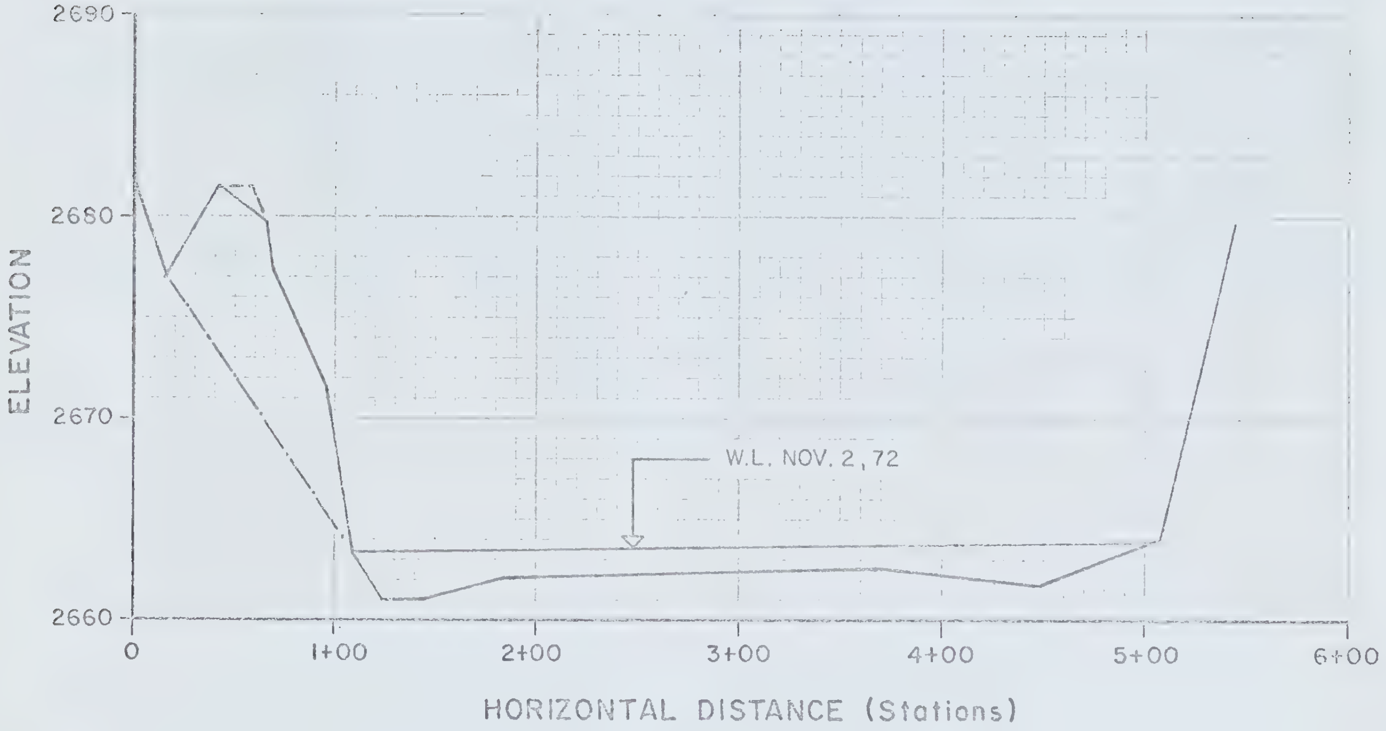
CROSS-SECTION 136-4

--- ESTIMATED ORIGINAL EMBANKMENT

-·- ESTIMATED ORIGINAL CHANNEL

FOR GEODETIC ELEVATION ADD 3.5 FEET

## SMOKY RIVER

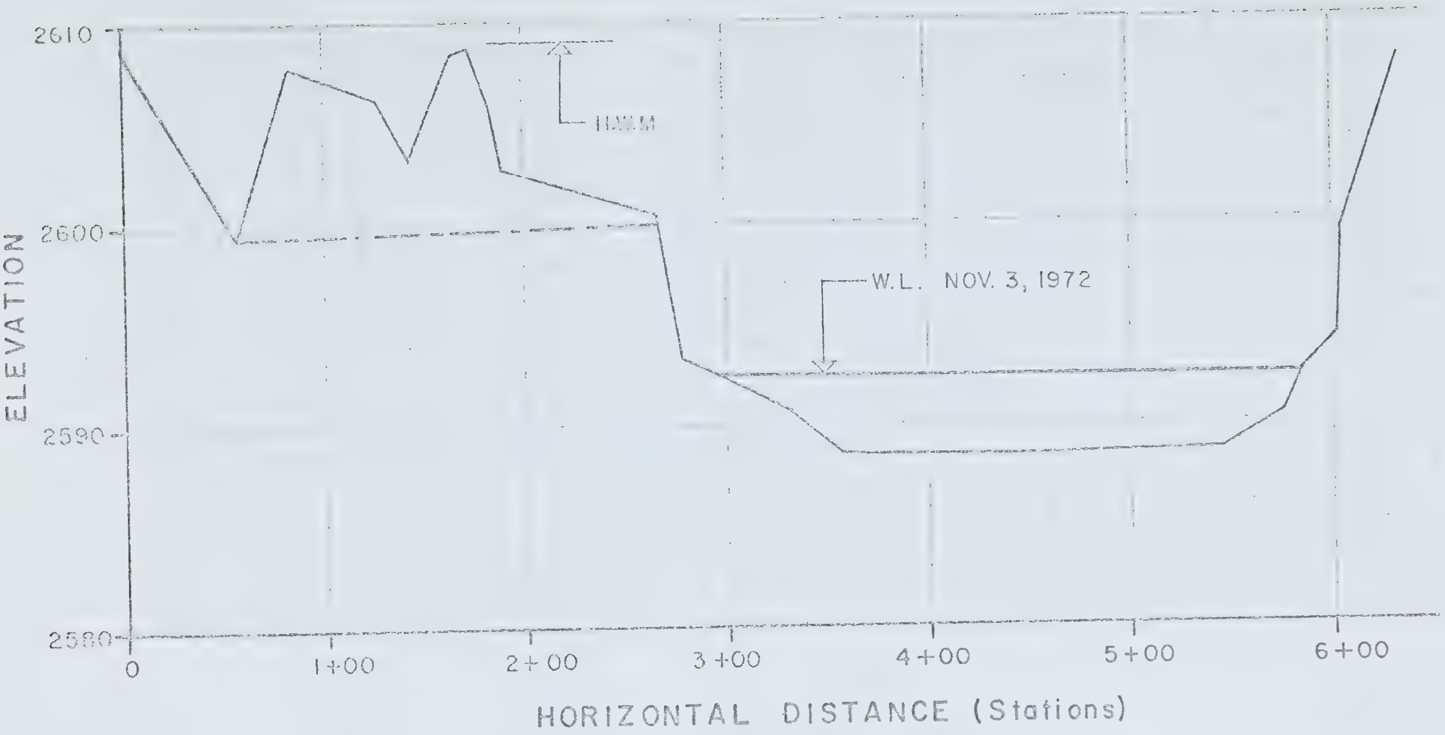


CROSS-SECTION 136-7

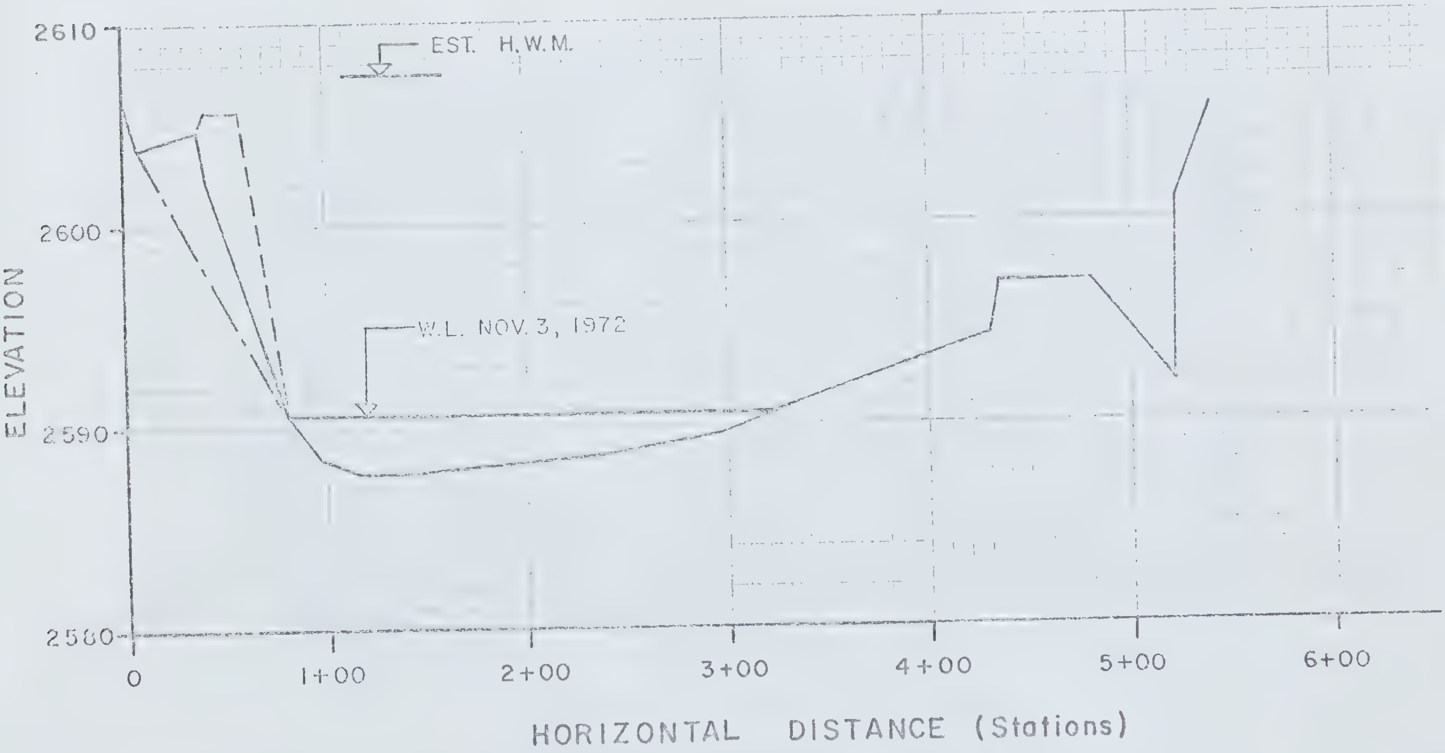
# SMOKY RIVER

– – – ESTIMATED ORIGINAL EMBANKMENT
—·— ESTIMATED ORIGINAL CHANNEL

FOR GEODETIC ELEVATION ADD 3.5 FEET



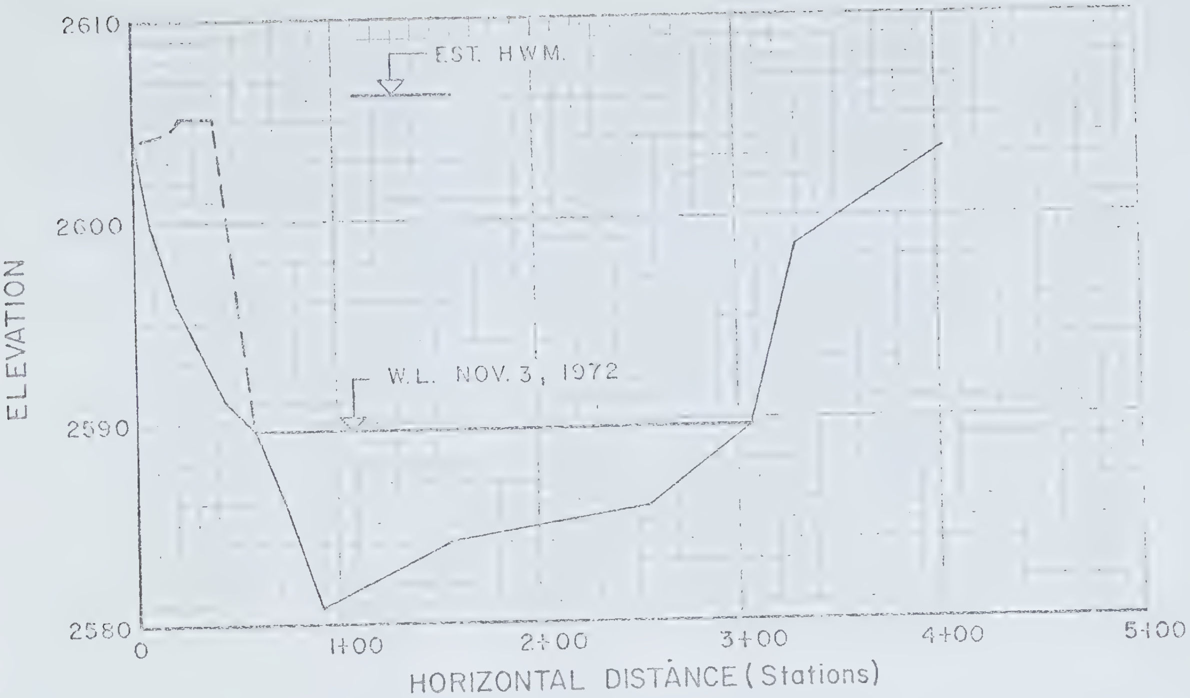
CROSS-SECTION 144-1



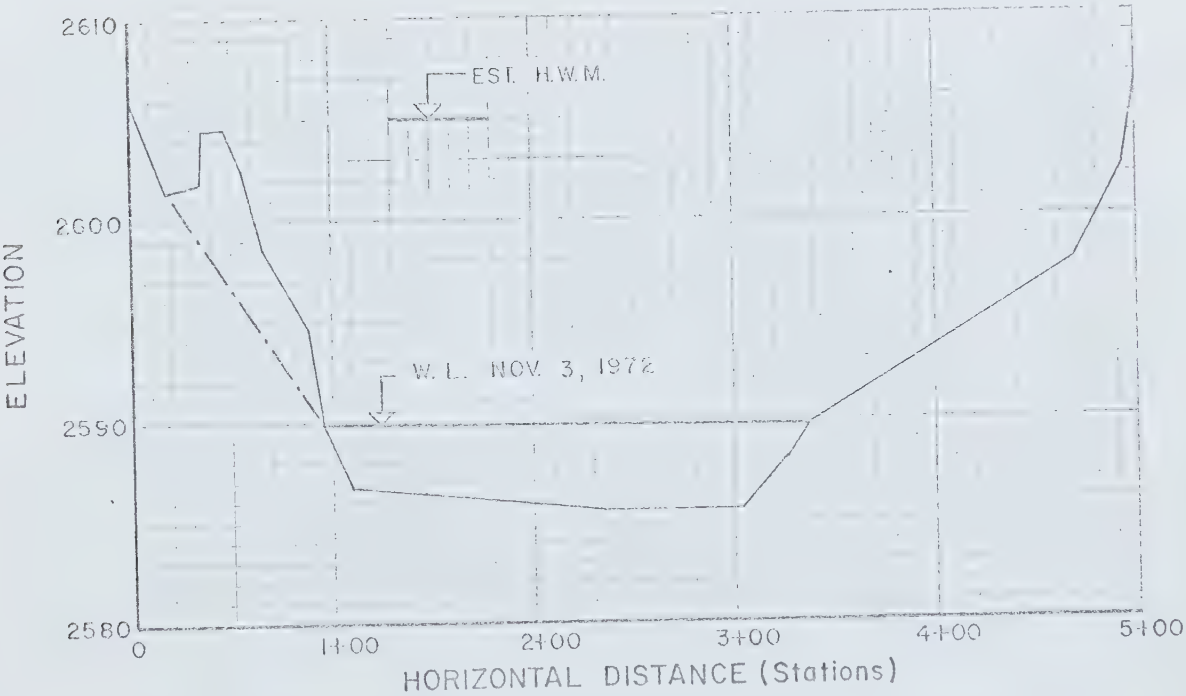
CROSS-SECTION 144-2

— — — ESTIMATED ORIGINAL EMBANKMENT
—·— ESTIMATED ORIGINAL CHANNEL
FOR GEODETIC ELEVATION ADD 3.5 FEET

# SMOKY RIVER



CROSS-SECTION 144-3



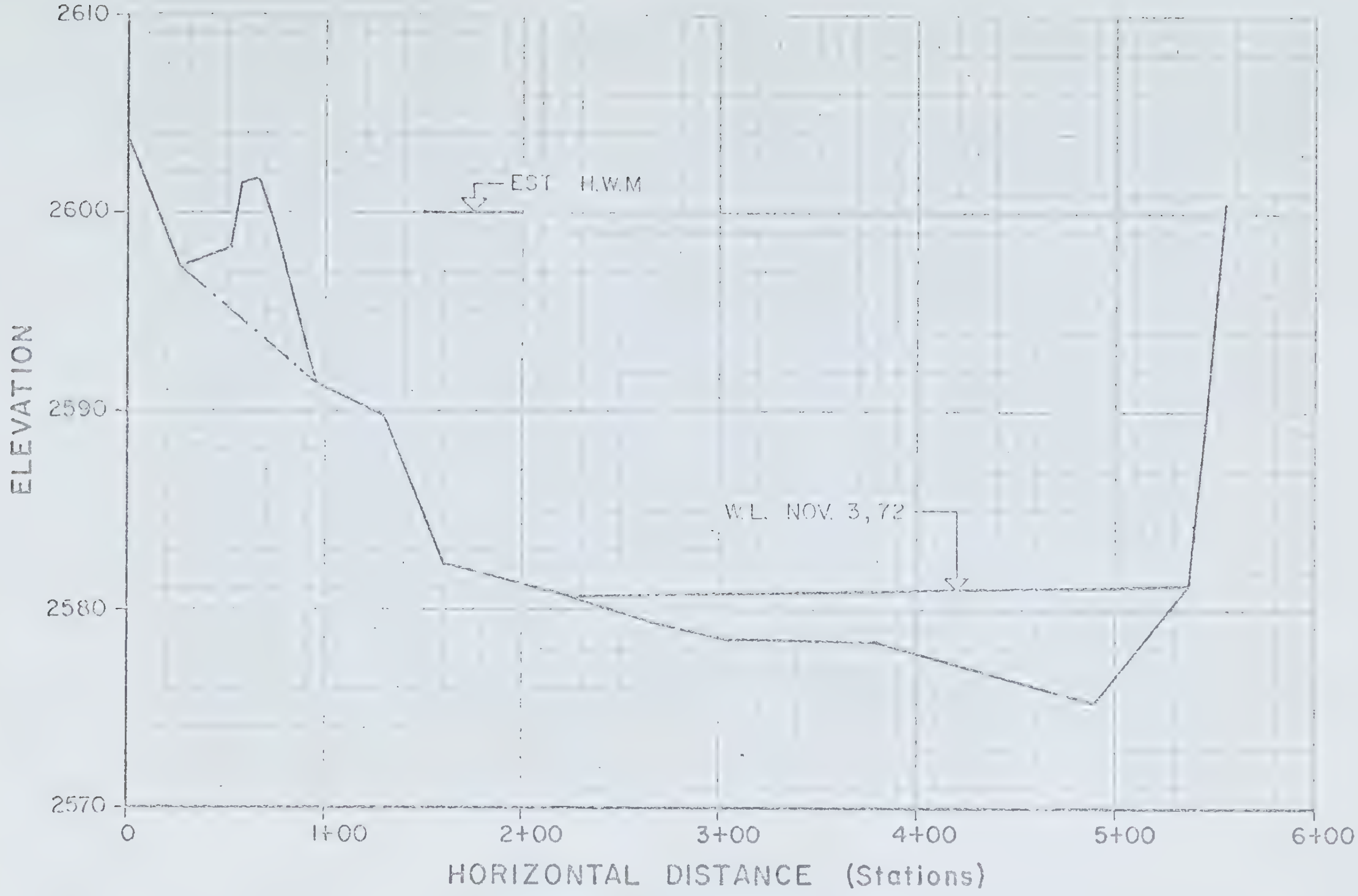
CROSS-SECTION 144-4

— — ESTIMATED ORIGINAL EMBANKMENT

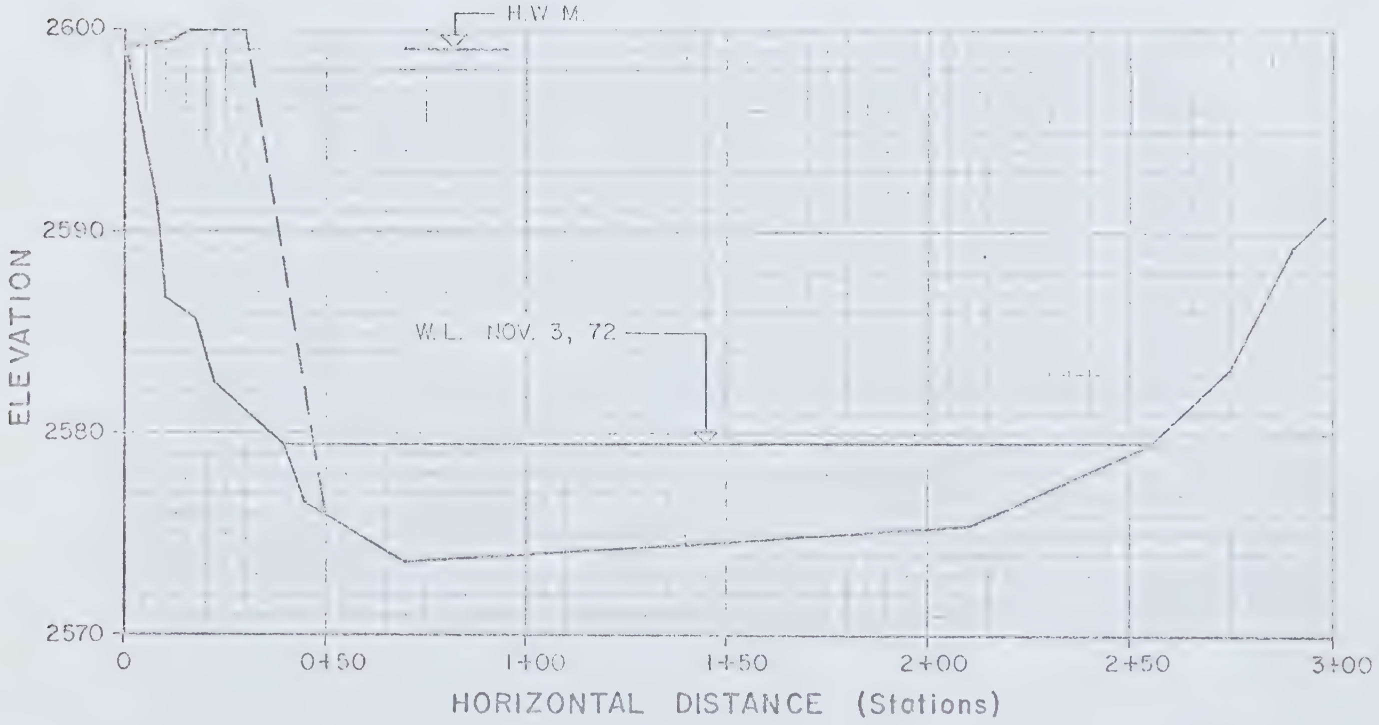
—·— ESTIMATED ORIGINAL CHANNEL

FOR GEODETIC ELEVATION ADD 3.5 FEET

SMOKY RIVER



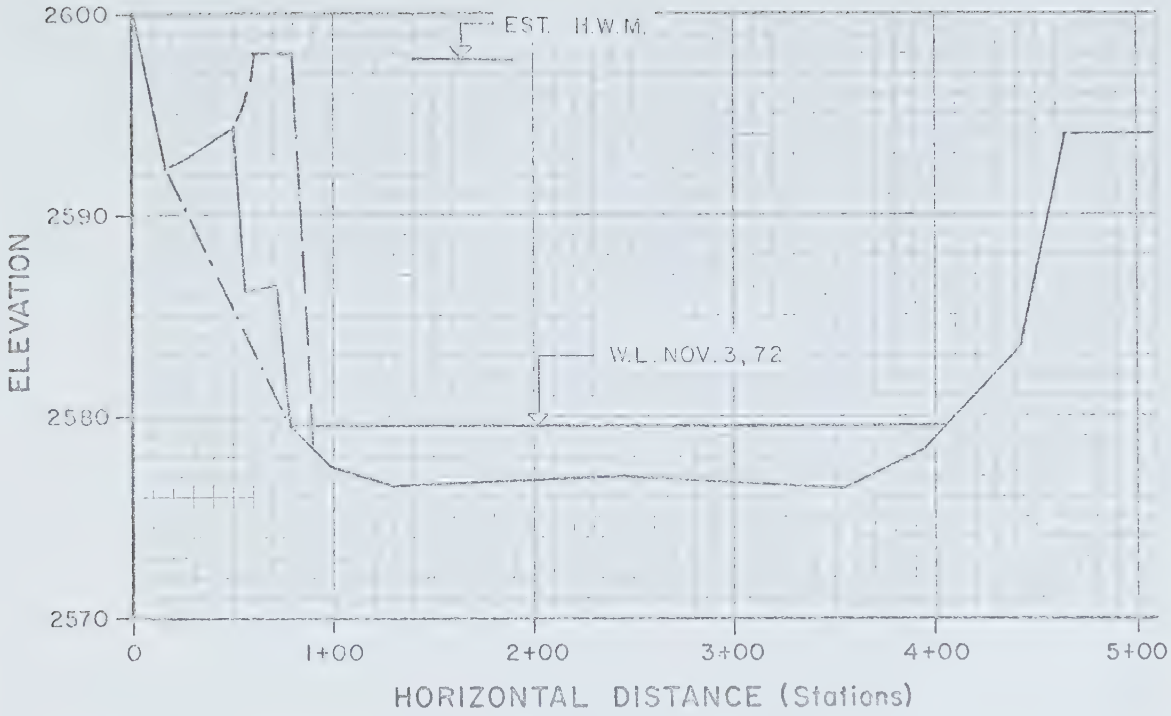
CROSS-SECTION 144-5



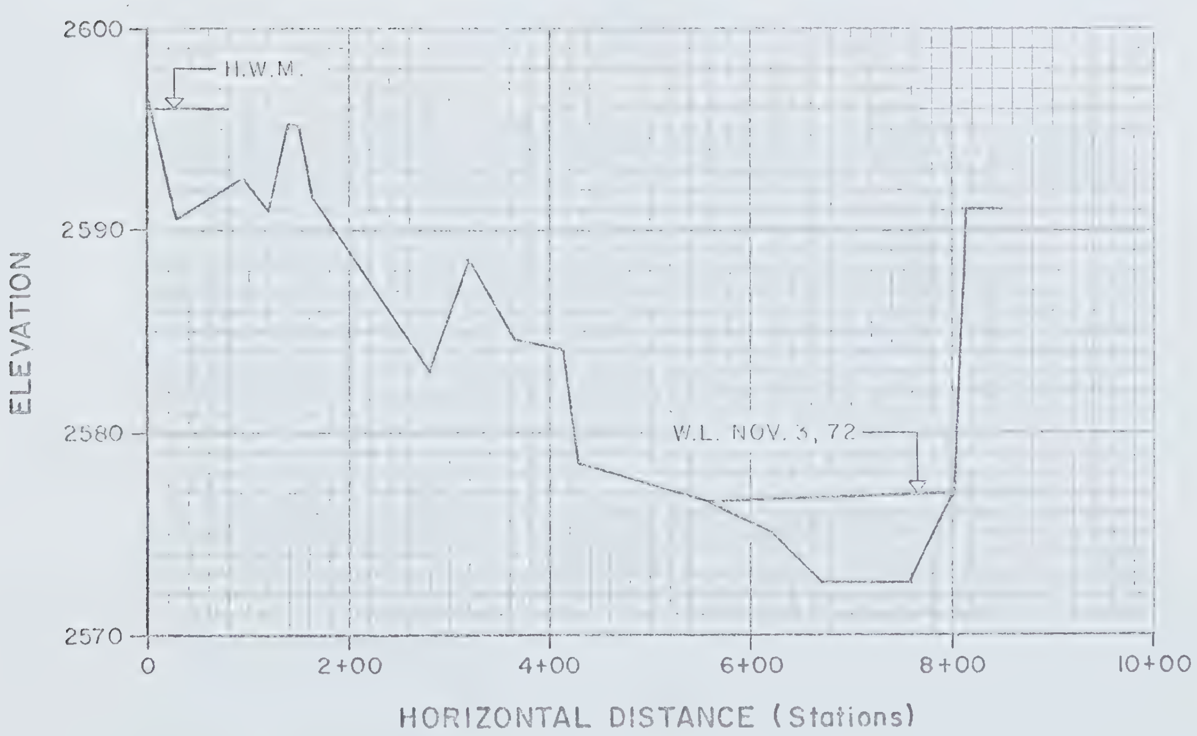
CROSS-SECTION 144-6

— — ESTIMATED ORIGINAL EMBANKMENT
—·— ESTIMATED ORIGINAL CHANNEL
FOR GEODETIC ELEVATION ADD 3.5 FEET

# SMOKY RIVER



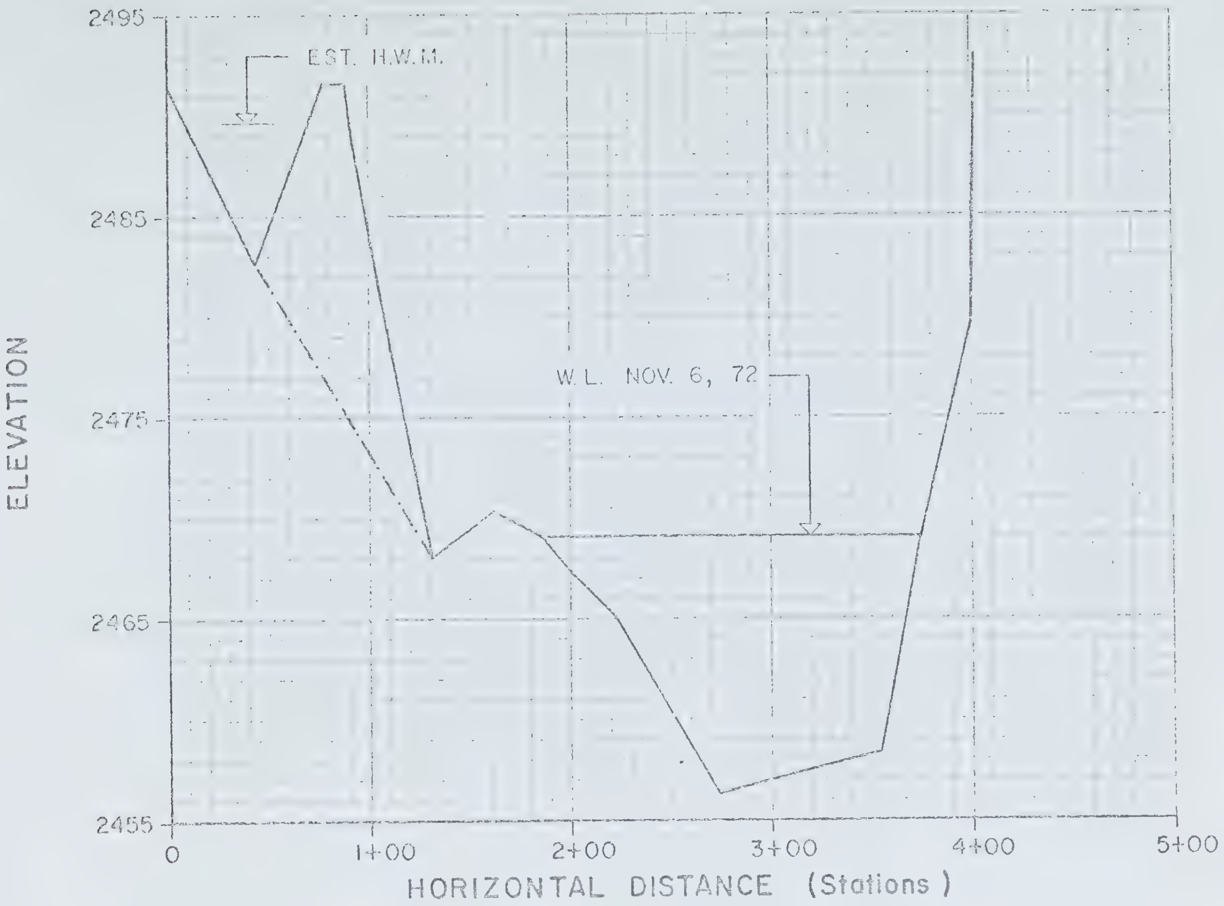
CROSS-SECTION 144-7



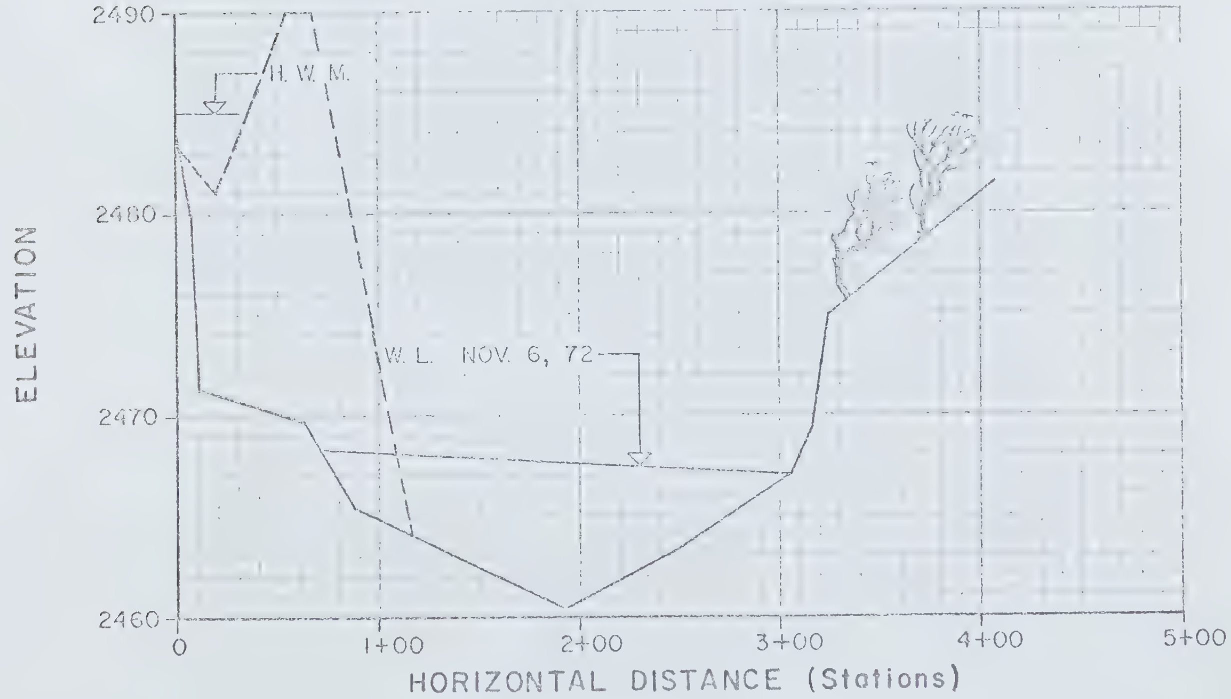
CROSS-SECTION 144-8

— —ESTIMATED ORIGINAL EMBANKMENT
—·—ESTIMATED ORIGINAL CHANNEL
FOR GEODETIC ELEVATION ADD 3.5 FEET

SMOKY RIVER



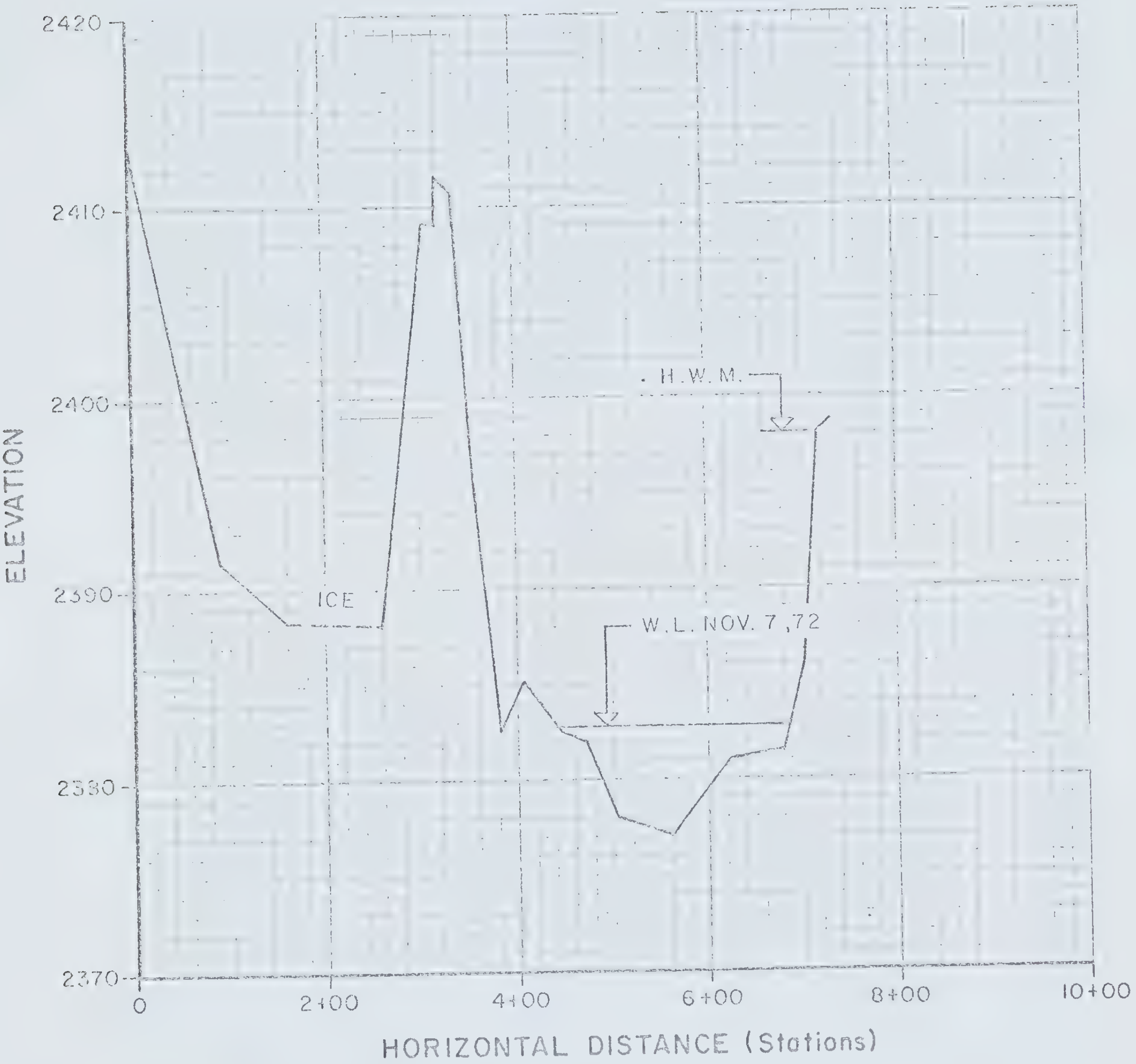
CROSS-SECTION 155 - 1



CROSS-SECTION 155 - 2

- - - ESTIMATED ORIGINAL EMBANKMENT
-·-·- ESTIMATED ORIGINAL CHANNEL
FOR GEODETIC ELEVATION ADD 3.5 FEET

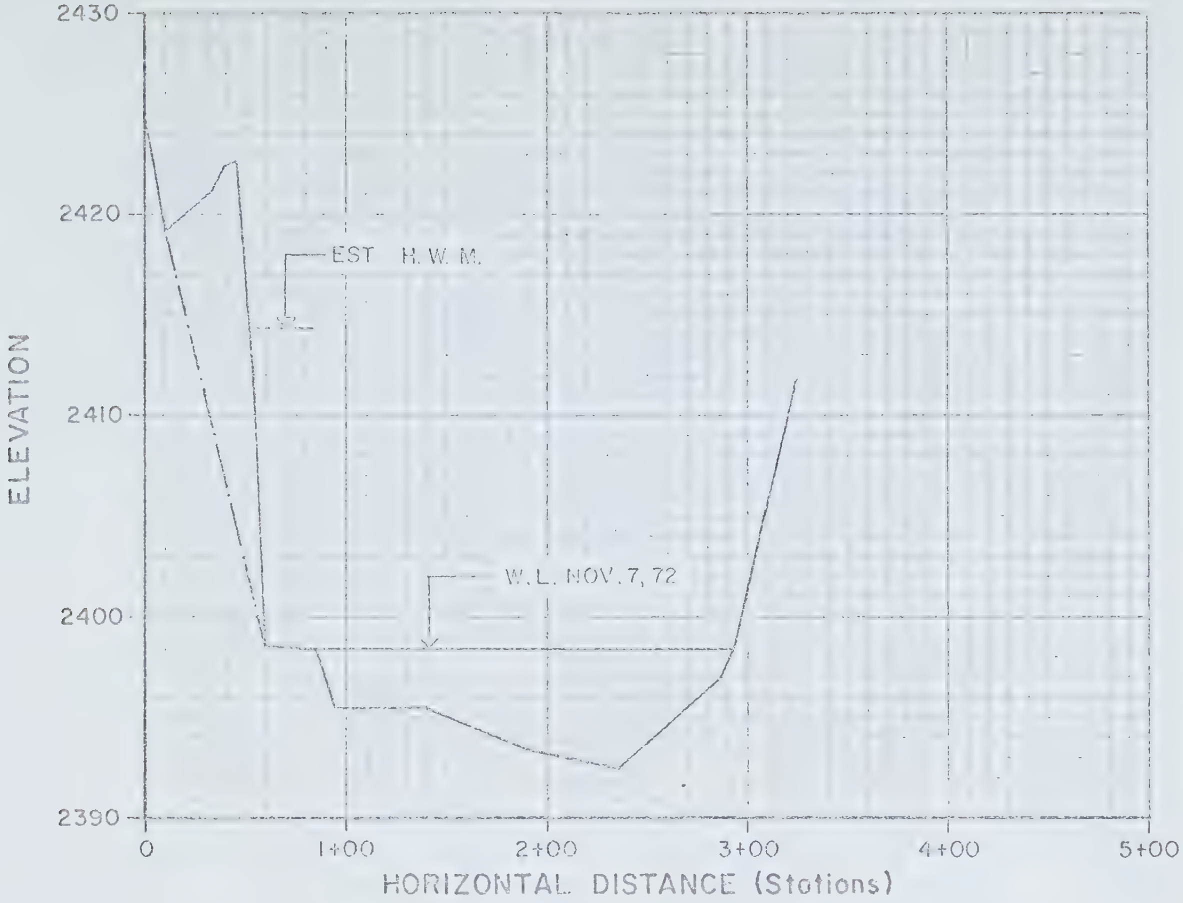
## SMOKY RIVER



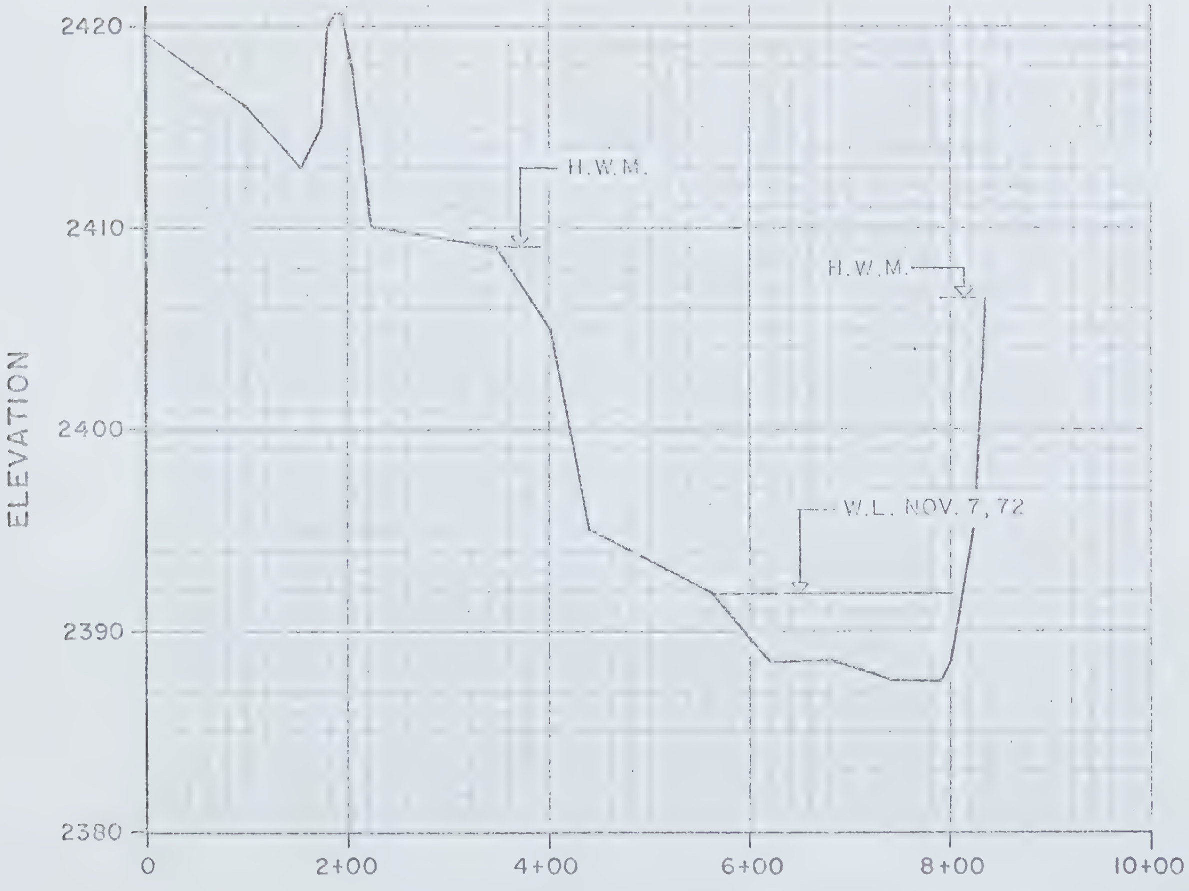
CROSS-SECTION 161.5-5

FOR GEODETIC ELEVATION ADD 3.5 FEET

SMOKY RIVER



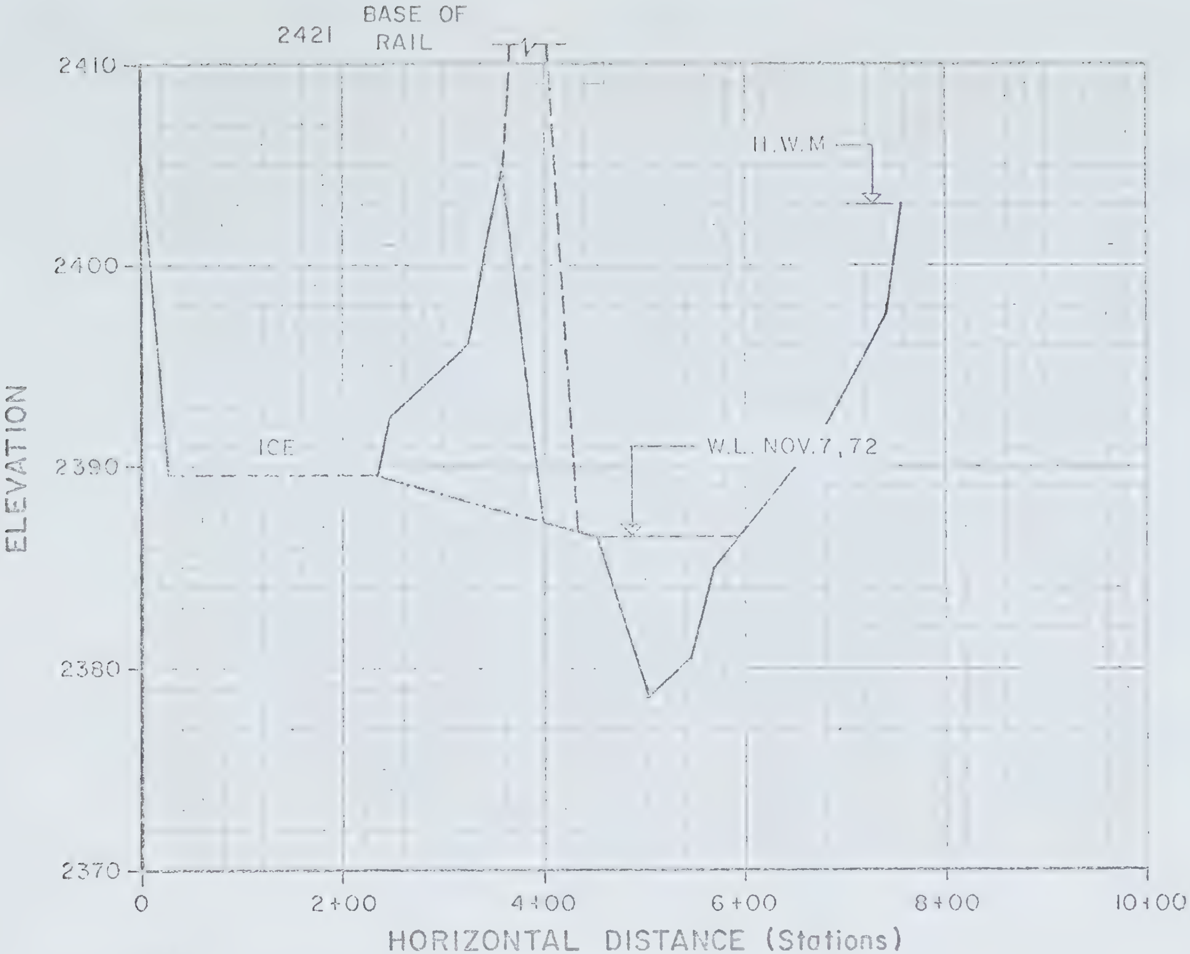
CROSS-SECTION 161.5-1



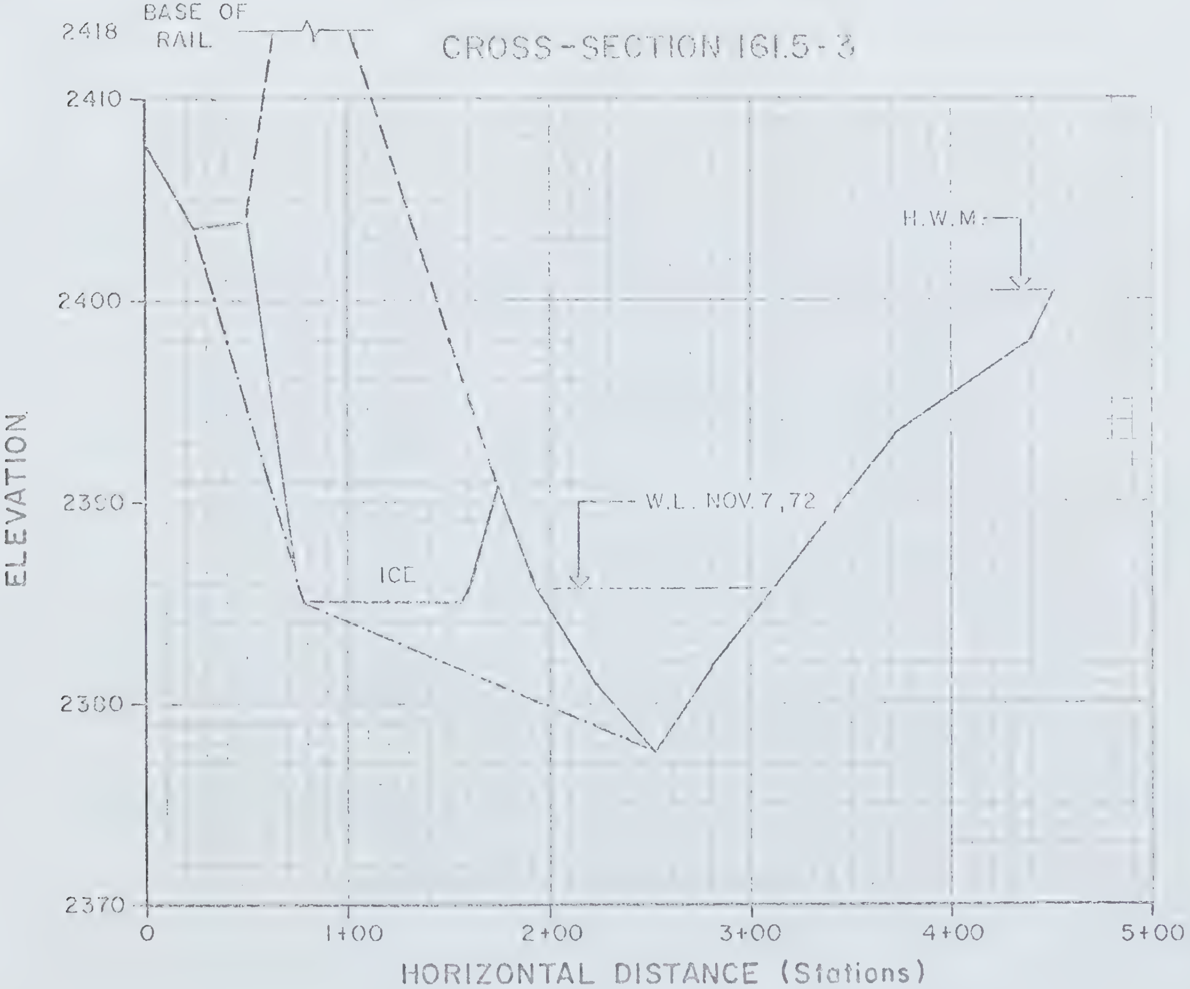
CROSS-SECTION 161.5-2

—·— ESTIMATED ORIGINAL CHANNEL
FOR GEODETIC ELEVATION ADD 3.5 FEET

SMOKY RIVER



CROSS-SECTION 161.5-3



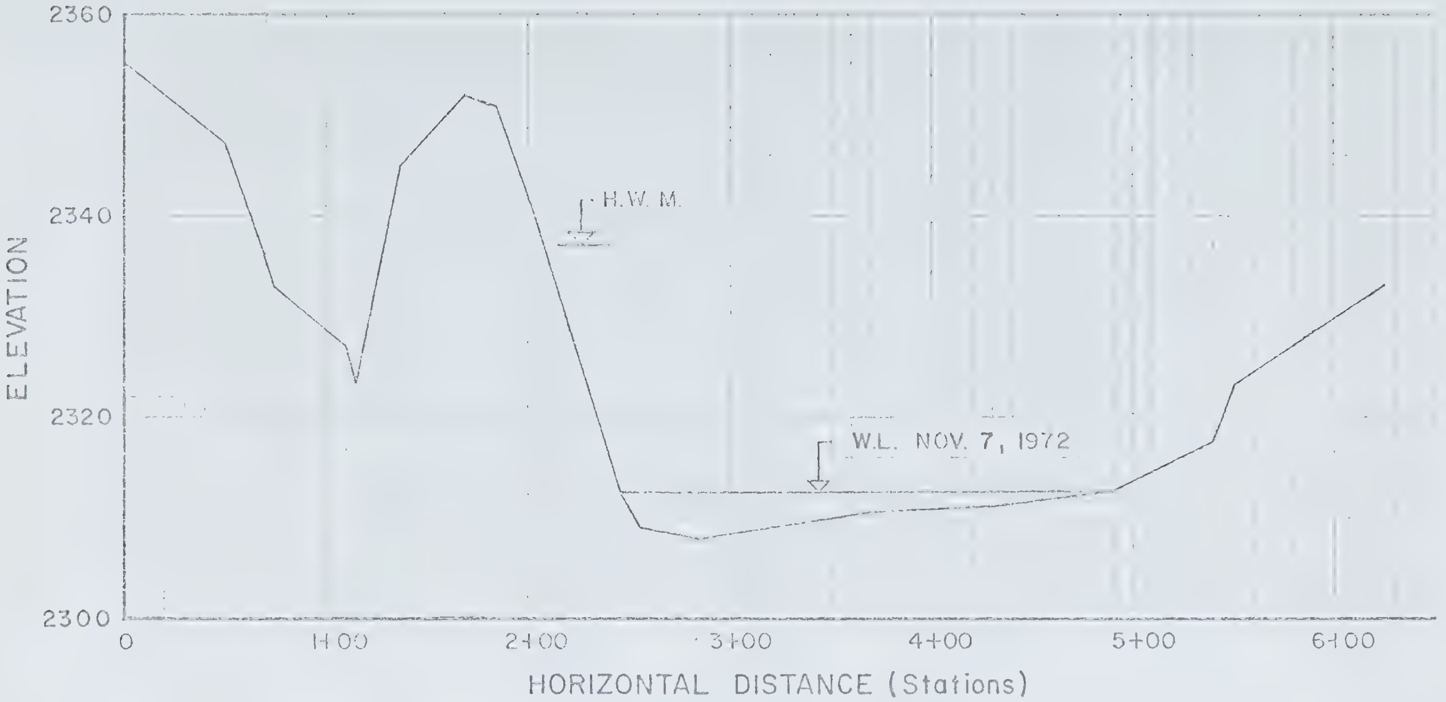
CROSS-SECTION 161.5-4

--- ESTIMATED ORIGINAL EMBANKMENT

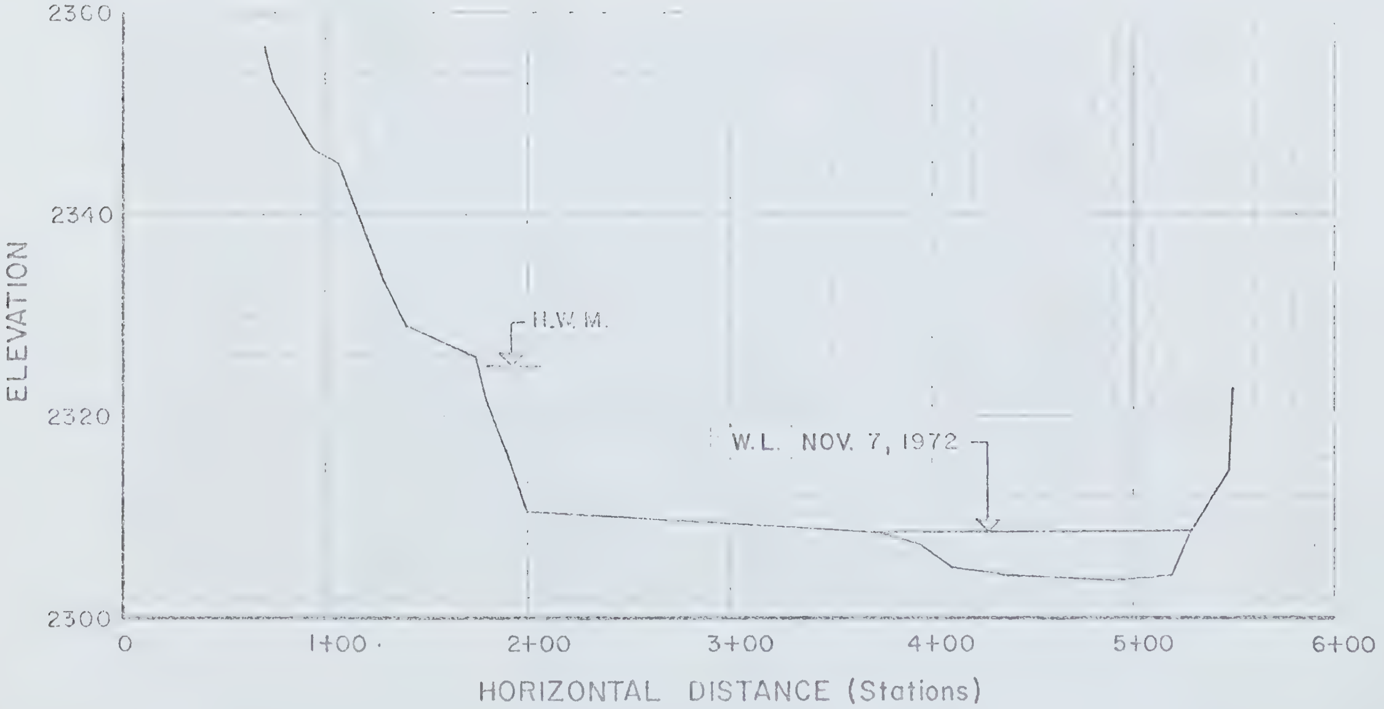
-·- ESTIMATED ORIGINAL CHANNEL

FOR GEODETIC ELEVATION ADD 3.5 FEET

SMOKY RIVER



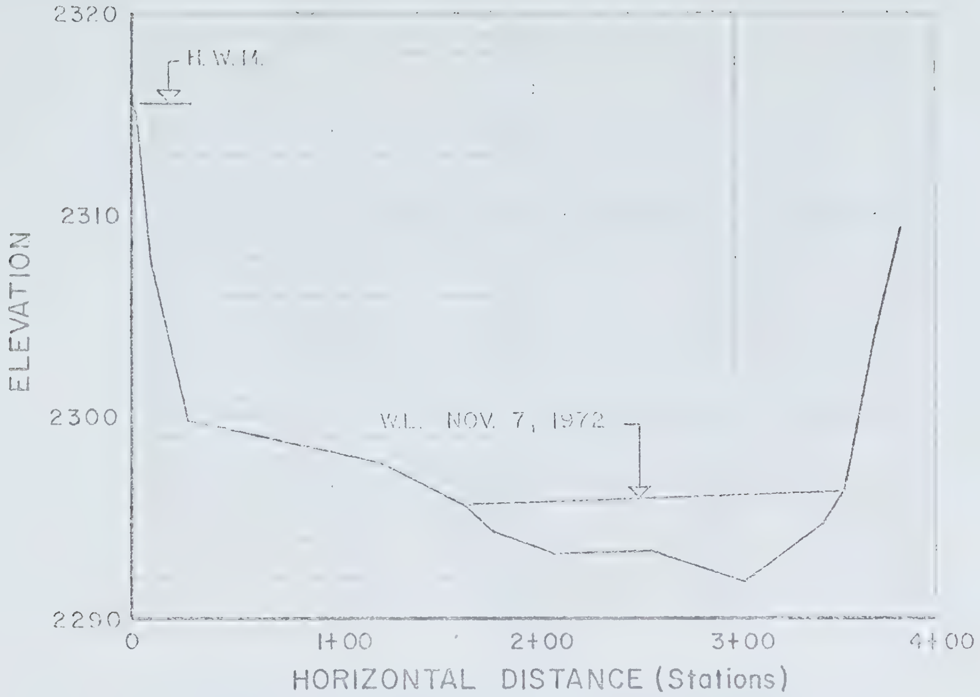
CROSS-SECTION 169-1



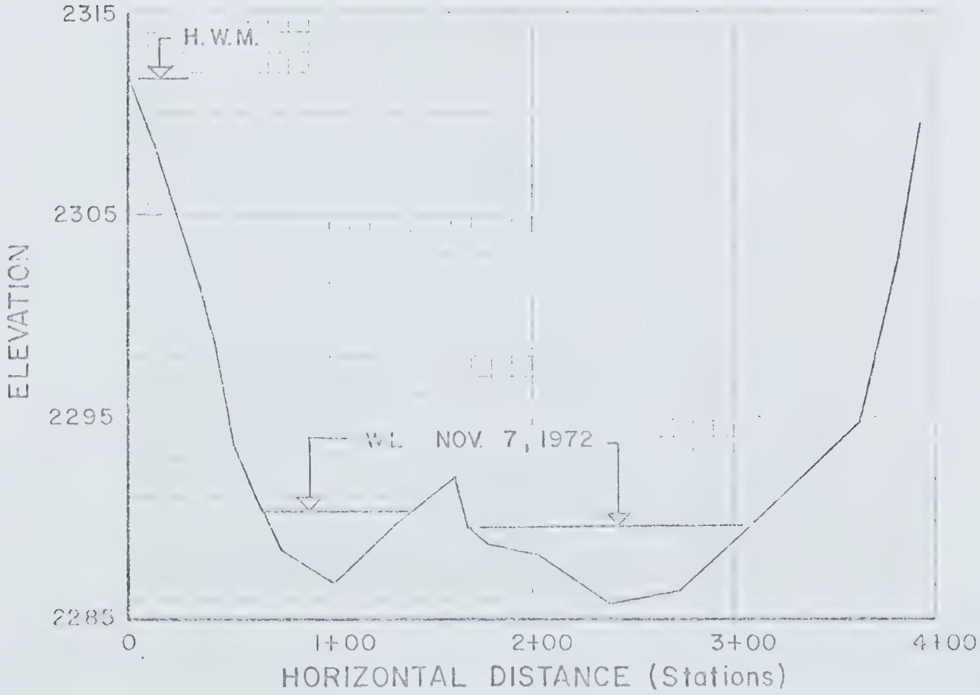
CROSS-SECTION 169-2

# SMOKY RIVER

FOR GEODETIC ELEVATION ADD 3.5 FEET



CROSS-SECTION 169-3



CROSS-SECTION 169-4

## SMOKY RIVER

FOR GEODETIC ELEVATION ADD 3.5 FEET

# APPENDIX D

## Repair of the Alberta Resources Railway

# APPENDIX D

## Repair of the Alberta Resources Railway

Appendix D deals with the problem of determining the probable costs of repairing the Alberta Resources Railway from Mile 105 to Mile 169, or that section of track situated within the left floodplain of the Smoky River. The estimated cost includes supply of bank armouring, embankment repair, river training works (spurs), roadbed and track replacement and culvert installations. The most important factor is bank armouring and this is dealt with in some detail.

D.1 Bank Protection; the basic stipulation underlying the requirements for armouring is that the sandstone rock previously used is not an acceptable bank protection material. The following design for rip rap is based on the requirement that limestone rock, or any other material of proven comparable durability if one can be found in the area, will be used for armouring. No consideration should be given to using any sandstone or shale bedrock derivative.

Using the hydraulic factors computed in Appendix C as a guide, four classes of rip rap material were delineated, each one being designed to withstand certain channel velocities. Generally the greater the angle of approach to a section of bank from upstream and the greater the amount of constriction of the channel imposed by the A.R.R. embankment, then the heavier (larger) would have to be the rock used. The specifications for these four classes of rock are as follows:

Class I for Tangential velocity = 24 ft/sec. (1.6 mean upstream approach velocity)
Extreme angle of attack ( 90°)
Constricted channel

* 100% smaller than 76" or 35,000 lbs.
At least 20% larger than 63" or 20,000 lbs.
At least 50% larger than 52" or 14,000 lbs.
At least 90% larger than 32" or 3,000 lbs.
100% larger than 24" or 1,500 lbs.

Class II for Tangential velocity = 20 ft/sec. (1.4 mean upstream approach velocity)
Very tight bend (60° - 90°)
Constricted channel

100% smaller than 60" or 20,000 lbs.
At least 20% larger than 49" or 12,000 lbs.
At least 50% larger than 37" or 5,000 lbs.
At least 90% larger than 26" or 1,700 lbs.
100% larger than 20" or 750 lbs.

Class III for Tangential velocity of 18 ft/sec. (1.3 mean upstream approach velocity)
Moderate bend (30° - 60°)
Constricted channel

100% smaller than 47" or 7,000 lbs.
At least 20% larger than 39" or 2,500 lbs.
At least 50% larger than 30" or 1,500 lbs.
At least 90% larger than 17" or 250 lbs.
100% larger than 10" or 50 lbs.

Class IV for Tangential velocity of 14 ft/sec.
Mild bend or straight channel
Constricted channel

100% smaller than 33" or 2,000 lbs.
At least 20% larger than 24" or 700 lbs.
At least 50% larger than 20" or 400 lbs.
At least 90% larger than 11" or 70 lbs.
100% larger than 6" or 10 lbs.

The rock would be placed on a prepared 2:1 slope and it is assumed that a filter blanket would not be required if adequate amounts of "chinking" material are placed in the interstices of the rip rap. Rock sizes should be increased by ten percent if 1.5:1 slope is used rather than 2:1.

*Note; gradation curve as suggested by C.R. Neill, Technical Note, Rip Rap Specifications, R.C.A. 1968.

After careful consideration of air photographs the writer delineated those reaches of river bank which were thought to require armouring. The location and class of rip rapping derived is shown on the air photographs in Appendix A where the heavy black lines are the suggested reaches to be protected and the Roman numerals specify the class of rock thought to be necessary. In addition spurs have been placed at various locations where it was felt they would save on the amount of bank armouring.

Table D.1 is a summary of the information given on the Appendix A photographs. Where it was felt that an apron would be desirable a design depth of scour value is provided. Apron rock would be the same class as specified for the adjacent bank being protected. In computing volumes of rock it was assumed that one layer of rock over the embankment slope and launched apron would be equivalent to a thickness of 1.5 times the $D_{50}$ size of armouring material used. It was also assumed that the embankment would on the average be protected to a vertical height of twenty feet above the river bed at the toe of the embankment.

Volume and weight of rock required to carry out the amount of bank armouring suggested above is as follows:

Apron material - 700,000 tons or 470,000 $yd^3$
Slope material - 1,800,000 tons or 1,200,000 $yd^3$
Total 2,500,000 tons 1,670,000 $yd^3$

These amounts include requirements for the proposed system of spurs.

Source of rock; the closest location of limestone is likely some sixty miles west of Grande Cache, in the front range of the Rocky Mountains. However, from discussions with some McIntyre-Porcupine

TABLE D.1

## ESTIMATED REACHES OF THE SMOKY RIVER REQUIRING BANK PROTECTION

l - length of bank along river

$d_s$ - estimated scour depth for falling apron design

| Location Mile | Class I | | Class II | | Class III | | Class IV | | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | l | $d_s$ | l | $d_s$ | l | $d_s$ | l | $d_s$ | |
| 104.94 | | | 300 | 15 | | | | | Spur |
| 106.10 to 106.90 | | | | | 4800 | 10 | | | Bank |
| 107.34 | | | 450 | 15 | | | | | Spur |
| 107.68 | | | 450 | 15 | | | | | Spur |
| 107.81 to 108.75 | | | 1450 | 10 | 3200 | 5 | | | Bank |
| 109.57 | | | 350 | 15 | | | | | Spur |
| 109.76 | | | 350 | 15 | | | | | Spur |
| 110.00 | | | 350 | 15 | | | | | Spur |
| 110.22 | | | 350 | 15 | | | | | Spur (New) |
| 110.45 | | | 350 | 15 | | | | | Spur (New) |
| 110.65 | | | 350 | 15 | | | | | Spur (New) |
| 110.85 | | | 400 | 15 | | | | | Spur (New) |
| 111.06 to 112.06 | | | | | | | 5300 | 5 | Bank |
| 113 | | | 400 | 10 | | | | | Spur |
| 114.17 to 114.42 | | | | | 2200 | 10 | | | Bank |
| 117.04 | 400 | 15 | | | | | | | Spur (New) |
| 117.17 | 400 | 15 | | | | | | | Spur (New) |
| 117.32 | | | 400 | 10 | | | | | Spur (New) |
| 117.47 | | | 400 | 15 | | | | | Spur (New) |
| 118.08 to 118.60 | | | 3200 | 10 | | | | | Bank |
| 118.60 to 118.81 | | | | | 1100 | | | | Bank |
| 119.28 to 119.35 | | | | | 400 | 5 | | | Bank |
| 119.35 to 119.63 | | | 1500 | 10 | | | | | Bank |
| 119.63 to 119.67 | | | | | | | 200 | | Bank |
| 121.53 to 121.61 | | | | | 400 | | | | Bank |
| 121.61 to 121.89 | 2000 | 20 | | | | | | | Bank |
| 121.89 to 122.06 | | | 900 | | | | | | Bank |
| 122.64 to 122.75 | | | | | 500 | 5 | | | Bank |
| 122.75 to 123.10 | | | 2000 | 10 | | | | | Bank |
| 123.10 to 123.46 | | | | | 1900 | | | | Bank |
| 124.25 to 124.48 | | | | | 1200 | 5 | | | Bank |
| 124.48 to 124.80 | | | 1700 | 10 | | | | | Bank |
| 124.80 to 124.99 | | | | | 1000 | | | | Bank |
| 126.20 | | | 400 | 10 | | | | | Spur (New) |
| 126.40 | 400 | 15 | | | | | | | Spur (New) |
| 126.60 | 400 | 15 | | | | | | | Spur (New) |
| 126.73 | 400 | 15 | | | | | | | Spur (New) |
| 126.83 | 400 | 15 | | | | | | | Spur (New) |
| 126.93 | 400 | 10 | | | | | | | Spur (New) |
| 127.08 | | | 500 | 15 | | | | | Spur (New) |
| 127.23 | | | 500 | 10 | | | | | Spur (New) |
| 127.72 to 128.08 | | | | | 1900 | 10 | | | Bank |

TABLE D.1 cont.

| Location Mile | Class I | | Class II | | Class III | | Class IV | | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | l | $d_s$ | l | $d_s$ | l | $d_s$ | l | $d_s$ | |
| 128.08 to 128.34 | | | 1400 | 10 | | | | | Bank |
| 128.34 to 128.66 | 1700 | 15 | | | | | | | Bank |
| 128.66 to 128.96 | | | | | 1600 | | | | Bank |
| 129.4 to 129.51 | | | 600 | 10 | | | | | Bank |
| 129.51 to 129.74 | 1200 | 15 | | | | | | | Bank |
| 129.74 to 130.06 | | | 1700 | 10 | | | | | Bank |
| 130.06 to 130.60 | | | | | 2700 | | | | Bank |
| 130.70 | | | 200 | 10 | | | | | Spur (New) |
| 130.82 to 130.90 | | | 400 | 5 | | | | | Bank |
| 130.90 to 131.14 | 700 | 10 | | | | | | | Bank |
| 131.14 to 131.42 | | | 1500 | 5 | | | | | Bank |
| 131.42 to 131.65 | | | | | 1200 | | | | Bank |
| 132 to 132.08 | | | | | 400 | | | | Bank |
| 132.08 to 132.25 | | | 900 | 10 | | | | | Bank |
| 132.25 to 132.59 | 1800 | 10 | | | | | | | Bank |
| 132.59 to 132.87 | | | | | 1200 | | | | Bank |
| 133.22 to 133.66 | | | | | | | 2300 | | Bank |
| 134.08 to 134.49 | | | 2000 | 10 | | | | | Bank |
| 134.49 to 135.42 | | | | | 5100 | 5 | | | Bank |
| 136 to 136.57 | | | 3000 | 5 | | | | | Bank |
| 136.57 to 137.47 | | | | | 4750 | | | | Bank |
| 138.00 to 138.42 | | | 2200 | 5 | | | | | Bank |
| 138.42 to 138.98 | | | | | 2960 | 5 | | | Bank |
| 139.30 to 140.08 | | | | | 3700 | | | | Bank |
| 140.28 to 140.62 | | | | | 1800 | | | | Bank |
| 140.72 | | | 300 | 10 | | | | | Spur (New) |
| 140.83 | | | 300 | 10 | | | | | Spur (New) |
| 141.17 to 141.40 | | | 1200 | 10 | | | | | Bank |
| 141.40 to 141.90 | | | | | 2650 | 5 | | | Bank |
| 141.90 to 142.17 | | | 1430 | 10 | | | | | Bank |
| 142.17 to 142.69 | | | | | 2750 | | | | Bank |
| 142.69 to 143.15 | 800 | 10 | | | | | | | Bank |
| 143.15 to 143.30 | | | 800 | | | | | | Bank |
| 143.73 to 143.87 | | | 700 | | | | | | Bank |
| 143.87 to 144.15 | 1600 | 10 | | | | | | | Bank |
| 144.15 to 144.34 | | | | | 1000 | | | | Bank |
| 144.7 to 145.04 | | | 2000 | 10 | | | | | Bank |
| 145.88 to 146.29 | | | 2150 | 10 | | | | | Bank |
| 146.29 to 146.54 | | | | | 1300 | 5 | | | Bank |
| 146.71 | | | 350 | 15 | | | | | Spur (New) |
| 146.85 | | | 350 | 15 | | | | | Spur (New) |
| 146.90 | | | 350 | 15 | | | | | Spur (New) |
| 147.06 | | | 350 | 15 | | | | | Spur (New) |
| 147.21 | | | 350 | 15 | | | | | Spur (Repair) |
| 147.36 | | | 350 | 15 | | | | | Spur (Repair) |
| 147.55 to 147.70 | | | | | 800 | 10 | | | Bank |
| 147.70 to 148.00 | 1450 | 10 | | | | | | | Bank |
| 148.45 to 148.68 | 1200 | 10 | | | | | | | Bank |
| 148.68 to 149.15 | | | 2500 | 5 | | | | | Bank |
| 149.15 to 149.40 | | | | | 1300 | | | | Bank |
| 149.98 | | | | | 350 | 15 | | | Spur (New) |
| 150.08 | | | | | 350 | 15 | | | Spur (New) |

TABLE D.1 cont.

| Location Mile | Class I |  | Class II |  | Class III |  | Class IV |  | Comments |
|---|---|---|---|---|---|---|---|---|---|
|  | l | $d_s$ | l | $d_s$ | l | $d_s$ | l | $d_s$ |  |
| 150.30 to 150.63 | 1760 | 15 |  |  |  |  |  |  | Bank |
| 150.63 to 151.51 |  |  | 4600 | 10 |  |  |  |  | Bank |
| 152 to 152.38 |  |  | 2000 | 10 |  |  |  |  | Bank |
| 152.38 to 152.53 |  |  |  |  | 800 |  |  |  | Bank |
| 153.06 to 153.31 | 1350 | 15 |  |  |  |  |  |  | Bank |
| 153.31 to 154.81 |  |  |  |  | 7900 |  |  |  | Bank |
| 154.81 to 155.04 |  |  | 1200 | 5 |  |  |  |  | Bank |
| 155.04 to 155.36 | 1700 | 15 |  |  |  |  |  |  | Bank |
| 155.36 to 155.59 |  |  | 1200 |  |  |  |  |  | Bank |
| 156.25 to 156.36 |  |  |  |  |  |  | 600 |  | Bank |
| 157.23 to 157.46 |  |  | 1200 | 10 |  |  |  |  | Bank |
| 157.46 to 157.73 | 1400 | 10 |  |  |  |  |  |  | Bank |
| 157.73 to 158.06 |  |  | 1740 | 10 |  |  |  |  | Bank |
| 158.45 to 158.58 |  |  |  |  | 700 |  |  |  | Bank |
| 158.58 to 158.77 |  |  | 1000 |  |  |  |  |  | Bank |
| 159.81 to 160.05 |  |  | 1200 | 10 |  |  |  |  | Bank |
| 160.05 to 160.51 |  |  |  |  | 2400 | 5 |  |  | Bank |
| 160.51 to 160.89 |  |  | 2000 | 10 |  |  |  |  | Bank |
| 160.89 to 161.15 |  |  |  |  | 1400 |  |  |  | Bank |
| 161.71 to 162.32 | 3220 | 15 |  |  |  |  |  |  | Bank |
| 162.32 to 162.51 |  |  | 1000 | 5 |  |  |  |  | Bank |
| 162.51 to 163.00 |  |  |  |  | 2400 |  |  |  | Bank |
| 163.00 to 163.23 |  |  | 1400 | 10 |  |  |  |  | Bank |
| 163.23 to 164.10 |  |  |  |  |  |  | 4600 |  | Bank |
| 164.70 to 164.97 |  |  |  |  | 1400 | 5 |  |  | Bank |
| 164.97 to 166.10 |  |  |  |  |  |  | 6000 |  | Bank |
| 166.55 |  |  |  |  | 350 | 10 |  |  | Spur (New) |
| 166.70 |  |  |  |  | 350 | 10 |  |  | Spur (New) |
| 166.83 to 168.00 |  |  |  |  | 6160 |  |  |  | Bank |
| 168.00 to 168.62 |  |  | 3300 | 10 |  |  |  |  | Bank |
| 168.62 to 168.92 |  |  |  |  | 1800 | 10 |  |  | Bank |
|  | 24680 |  | 66270 |  | 80170 |  | 21320 |  |  |

Mining personnel it was apparent that an adequate road to the site does not exist. It seems more logical to take advantage of C.N.R.'s equipment and track to haul in the rock from some easily accessible source. One possibility is the Inland Cement limestone quarry at Cadomin, some three hundred track miles to the south from the work area. Here loading facilities exist and unit trains hauling out the crushed limestone should be able to accommodate rip rap hauling cars at the same time.

Cost of rock; assuming that the job of hauling limestone rock could be handled by C.N.R. on an at-cost basis, the unit-cost of placing the rip rap was derived as follows:

| | | |
|---|---|---|
| Drill and blast rock | $\$1.00/yd^3$ | |
| Price of rock | $\$1.00/yd^3$ | |
| Loading and segregating rock | $\$1.00/yd^3$ | |
| Placing rock on slopes | $\$1.00/yd^3$ | |
| Hauling rock | $\$5.00/yd^3$ | (average) |
| Total | $\$9.00/yd^3$ | |

Cost of armouring bank; $1.6 \times 10^6 yd^3 \times \$9/yd^3 = \underline{\$14,500,000}$

One other source of rock not mentioned which may provide a cheaper unit price for rip rap is the use of a conglomerate rock which apparently exists near the mine-site. The exact location and quantity available should be pursued and durability tests carried out on the material. Some of it was noted mixed in with the sandstone rip rap and mine personnel talked to, believe it has a high degree of durability.

D.2 Embankment Reconstruction; for estimation purposes it has been assumed that 7.55 miles of embankment has to be completely replaced and that on the average another 7.80 miles requires twenty-five percent

replacement. It has been assumed that the original grade-line profile need not be raised. Even though it was overtopped at numerous locations in 1972 it was felt that in general the present grade does provide an acceptable risk factor against being overtopped. Any embankment which is properly armoured should be capable of being overtopped for a short period without sustaining a great deal of damage.

| | |
|---|---|
| Embankment Replacement<br>7.55 miles x $300,000 per mile | $2,260,000 |
| Embankment Repair<br>7.80 miles x 0.25 x $300,000 per mile | 590,000 |
| Replacing Ballast and Track Laying<br>7.55 miles x $162,000 per mile | 1,220,000 |
| Relaying Track (not including ballast) | 300,000 |
| Total | $4,370,000 |

D.3 Culvert Replacement; insufficient flow through capacity of culverts was responsible for some of the damage this year. Besides the complete loss of some culverts, there are others that have completely been filled with gravel. It is difficult at this point to be entirely sure of the amount of culvert replacement required but it has been assumed 4,000 feet of 10 gauge, 60 inch diameter C.I.P. will be required to complete the job.

| | |
|---|---|
| 4,000 feet @ $33.00 per foot | $ 130,000 |

D.4 Spurs

| | |
|---|---|
| Construction of shanks, noses of new spurs and repair of existing ones | $ 300,000 |

D.5 Channel Excavation; certain gravel islands or bars would require removal in order to improve channel capacity and flow direction. These

areas have been shaded on the air photographs of Appendix A and in general occur adjacent to systems of spurs.

| | |
|---|---|
| Excavation of channel material | $ 300,000 |

D.6 Total Cost; summing up the above costs:

| | |
|---|---|
| D.1 | $14,500,000 |
| D.2 | 4,370,000 |
| D.3 | 130,000 |
| D.4 | 300,000 |
| D.5 | 300,000 |
| Subtotal | $19,600,000 |
| Engineering and Contingencies (15%) | 3,000,000 |
| Total | $22,600,000 |

The biggest factor in the above cost estimate is that of bank armouring. It must be repeated that the unit cost of rip rapping embankment slopes has assumed that C.N.R. would haul rock (limestone) on an at-cost basis. If standard rates for hauling rock were necessary in the analysis, the unit cost for the armouring would be more than doubled and project costs would be prohibitive.

Cost could be reduced if it were definitely established that bedrock was near the bed all along the toe of the A.R.R. embankment. This would permit a substantial reduction in the volume of rock required for aprons. Therefore it would be to the benefit of the project cost if a drilling program were carried out to determine the bedrock profile along the track. Also because of the many uncertainties in rip rap design it would be extremely beneficial cost-wise if a few model studies

were carried out to determine the proper sizing of rock, the adequacy of the proposed rock placement techniques, and to determine the extent of rip rapping required around the various severe bends in the river.

# APPENDIX E

# FLOOD CONTROL DAM

## FLOOD CONTROL STORAGE IN THE SMOKY RIVER BASIN

### Introduction

The 1972 flood on the Smoky River caused extensive damage to the Alberta Resources Railroad. As shown on Figure 1 the railroad enters the Smoky River Valley north of Grande Cache and parallels the river northward for a distance of approximately 50 miles. Although a flood of the magnitude recorded in 1972 is estimated to be an infrequent event, the close proximity of the railroad to the river poses the threat of damage to the railroad whenever flows exceed the capacity of the river channel.

A study was initiated to determine means of reducing potential damage to the railroad facilities from future floods on the Smoky River. One means of achieving this is to control the flood by providing a flood storage reservoir in the Smoky River basin upstream of the railroad. This would allow a large portion of the runoff from severe storms to be stored and later released at a rate which did not exceed the river channel capacity. Protective measures along the area subject to damage coupled with works to increase the channel capacity could also achieve the same ends. It is quite possible that a combination of control and protective works would provide the optimum means to reduce potential damage.

This brief report is only one component of the overall study. It presents the results of a very preliminary review of the potential for providing upstream storage, the possible costs for a specified volume of storage and the implications associated with creating a major reservoir in this area.

## Scope and Level of Analysis

Due to the very limited hydrological, topographical and geologic data available, the scope of the study was confined to

i) estimating the volume of storage necessary to control a flood similar to that experienced in 1972 without exceeding specified downstream discharge rates.

ii) identifying potential dam sites to store this volume of water, and selection of a typical site to provide a basis for a preliminary cost estimate.

iii) a conceptual layout of the embankment and hydraulic works.

iv) a gross estimate of the order of magnitude of costs to construct the dam and associated facilities.

v) a review of other potential benefits which could accrue from such a project

vi) an overview of the impact such a project could have on the ecology of the area.

The level of study was dictated by the very limited data available and the short period in which to complete the work. The conclusions are based on an office study only. Storage sites were identified from National Topographic sheets, scale 1:50,000 with a 100 foot contour interval. Dam sites were selected from aerial photographs. Published bedrock geology maps were the only other aid in assessing the material available for construction and potential major problems. Embankment quantities are based on assumed dam sections, and valley cross sections from the 100 foot contours.

In summary the limited scope and very preliminary level of the analysis are emphasized, and must be recognized in applying the conclusions from the study.

## Identification of Potential Dam Sites

Although a number of possible storage sites exist downstream of the point at which the railroad joins the Smoky River valley, reservoir development in this reach would necessitate major realignment or relocation of existing track. Further, as almost 70 percent of the drainage basin contributing to the flooding problem is upstream of the point at which the railroad enters the valley, it was concluded that control of this upstream portion of the drainage basin should provide a high level of protection. Emphasis was placed, therefore, on identifying potential sites upstream of the point at which the railroad enters the valley.

In order to control as much of the headwaters of the Smoky River as possible, the search for suitable storage sites was limited to a 20 mile reach of the Smoky River, extending upstream from the existing railroad trestle as far as the Smoky River-Jackpine River confluence.

The Smoky River valley is quite uniform in this area, and is characterized by a 1500-2000 feet wide alluvial floor and mountainous valley walls rising at slopes of about 2:1 or 3:1. River gradient is in the order of 15 to 20 feet per mile.

An initial analysis indicated that between 200,000 and 250,000 acre-feet of storage would be required to control a flood similar to that experienced in 1972. It was realized early in the study that this magnitude of storage could be developed at any one of a number of locations. Four sites were located on 1:50,000 scale topographic maps with 100 foot contour intervals, and storage-area-elevation curves were prepared for each site. These sites are shown on Figure 1.

A review of existing bedrock data immediately disqualified site 4 as being in a major fault zone. The remaining 3 sites appeared quite similar from a cursory geological standpoint, and no major problems were

identified from the available bedrock mapping and aerial photography.

Development of a reservoir at site 1 near the railway trestle would flood the existing highway bridge near Grande Cache, along with transmission lines and pipelines located in the valley. Site 3, some seven miles upstream of Grande Cache, is located well within the boundary of Willmore Wilderness Provincial Park, and would be the least accessible of the three sites. Site 2, directly upstream of the highway bridge west of Grande Cache townsite, was selected as the representative site for estimating the magnitude of costs to provide a flood control reservoir. Detailed investigation of site geology, material availability, etc., might well indicate the superiority of an alternative location.

## Conceptual Design

In order to provide a gross estimate of potential costs, it was necessary to prepare a conceptual layout of the embankment and hydraulic works. This entailed making a number of broad assumptions related to the degree of flood control provided, the inflow hydrographs, and the physical characteristics of the site.

The assumed area-storage curve and valley cross section at the site are shown on Figures 2 and 3. These were derived from the 100 foot contour information on the 1:50,000 topographic sheets.

The conceptual layout adopted is shown on Figure 4.

Hydrologic Considerations: Figure 5, a hydrograph of the June, 1972 flood, represents graphically the discharge in time relationship of the June 1972 flood on the Smoky River at Hells Creek, near the existing Alberta Resources Railroad trestle. The area under the hydrograph represents the volume of water passing this particular river location which is estimated to be approximately 290,000 acre-feet above an assumed summer base flow of 10,000 cfs. Peak flow was in the order of 50,000 cfs.

The return frequency of a flood of this magnitude is estimated to be in the order of 1:50 to 1:100 years. It was specified that storage works be sufficient to control such a flood.

A reservoir at the selected site would not control flows from Sheep Creek and Muskeg River. It is therefore desirable that the discharge in the Smoky River be retarded until the peak flow from these tributaries has passed. It was indicated that a desirable reservoir operation schedule during the 1972 flood would have been to release a constant discharge of about 10,000 cfs from the reservoir during the storm until the damage threat had passed, and then to increase the reservoir release rate to some maximum discharge which would allow rapid storage drawdown in readiness for subsequent floods. This rate of discharge would be limited by the channel capacity along the downstream damage zone. Determination of the downstream channel capacity is part of the overall study, however, and for the purpose of this analysis maximum reservoir discharge was limited to 35,000 cfs.

Preliminary routing of the 1972 flood according to these criteria is shown on Figure 5. June 14, 2 days after peak inflow, was arbitrarily assigned as the time on the receeding hydrograph limb at which discharge could be increased above 10,000 cfs. Gates could be safely opened at this point, as the inflow peak of 50,000 cfs had passed, and inflow was about 25,000 cfs and decreasing rapidly. The reservoir could have been emptied over a period of 8 to 10 days at maximum reservoir discharge.

Assuming this operational procedure, a storage volume of about 215,000 acre-feet would have been needed to regulate the 1972 flood. From Figure 2, the storage-elevation curve, the maximum water level at the dam would have been about 190 feet above river level. The reservoir would have covered approximately 2500 acres.

It was assumed that during construction, the diversion works should pass at least the 1:35 year flood. Estimated peak inflow would be in the order of 35,000 cfs.

It is necessary that spillway and outlet works be capable of passing floods in excess of the 1972 design flood, although damage to the structure or downstream facilities may occur. The size of the structure and potential damage from failure dictate that the structure must stand under the probable maximum flood. No estimate of the probable maximum flood is presently available. A hydrograph peaking at about 90,000 cfs was assumed for an assessment of embankment height or outlet capacity required in addition to that for the 1972 flood.

Embankment Considerations: A zoned earth-fill dam has been assumed. Anticipated foundation and abutment conditions and general availability of materials indicate this to be the most likely choice.

Specific information is not available on quantity or quality of construction materials for an earth fill dam. Assessment of aerial photographs suggests that granular materials should be available in the terraces and river channel, and glacial deposits appear to mantle the highlands of the right abutment. Specific impervious deposits have not been located An undetermined depth of alluvium below the Smoky River channel and the condition of the abutments are the other major unknown factors which greatly affect the design and cost of dam construction in this area.

Alternative dam sections, each 200 feet high, were considered--one assuming a large available quantity of impervious material for use in constructing a thick impervious core and upstream blanket, and the other assuming minimal impervious material available thus requiring a thin impervious core with a deep concrete cutoff wall into the foundation. With the limited data available no attempt was made to formally prepare a preliminary

design. The sections assumed for estimating quantities were based largely on judgement and experience rather than detailed analysis due to the many unknowns. Estimated costs of each of the alternatives came to about the same figure. Much more detailed investigations would be necessary to indicate the probable dam section and provide a more reliable cost estimate.

Hydraulic Works: Examination of the topographic maps and aerial photographs did not reveal a suitable natural location for a flood or emergency spillway at this, or any of the other dam sites identified. For the purpose of estimating costs, it has been assumed that diversion tunnels required during construction will subsequently, with some modification serve as outlet works. Three 2000 foot concrete lined tunnels, each with a finished inside diameter of 20 feet, would be required. During construction, the tunnels could pass about 24,000 cfs at low head. A coffer dam approximagely 40 feet high would be necessary, however it would be incorporated into the main embankment. Control gates would subsequently be installed on the tunnels. At maximum head, each tunnel could discharge about 12,000 cfs at a velocity of some 40 feet per second. For a flood similar to that experienced in 1972, downstream river flows could be maintained at a level which would avoid damage to the Alberta Resources Railroad. As noted previously no estimate of the probable maximum flood is available. It is assumed that a relatively inexpensive rock cut emergency spillway would be provided. Approximately 30,000 acre-feet of additional storage would result from each incremental 10 feet of dam height above that necessary to control the 1972 level of flood. An increase in head would of course substantially increase the outlet works capacity. An economic analysis would be necessary to establish the optimum combination of dam height and spillway capacity and would take into account potential damage to the railroad facilities. For the purpose of this study a 10 percent increase in

embankment cost has been assumed.

## Estimated Costs

As noted previously, specific information is not available on the materials which may be available for construction of the embankment. To take this into account, two alternative sections were considered which incorporated very different assumptions as to material availability. Although the total costs estimated for the alternatives were comparable, in each case the cost would be very sensitive to a number of key factors.

The cost of the embankment incorporating a deep cutoff would be very sensitive to the cost of the filter material and other pervious borrow. The cost of filters varies with the type of granular material available and the processing that that material requires.

Cost of the embankment which includes an extensive upstream blanket would be very dependant upon the cost of providing the impervious material-particularly the haul distance involved.

Embankment costs are estimated to be in the order of $26.5 million.

No information is available on the conditions likely to be encountered in constructing the tunnels. The gross estimated cost therefore incorporates assumptions with respect to tunnelling methods and support, as well as configuration of transition sections, inlet and outlet works and control gates. Total cost of the three tunnels is estimated at $19 million.

It was assumed that purchase of the land for the reservoir would not be required as the area to be flooded is presently under crown ownership. A detailed assessment of the requirements for reservoir clearing would be necessary. A nominal $1.5 million has been included in the cost estimate for this item.

It is emphasized that the estimate of cost is extremely preliminary and is based on unknown conditions. The gross estimate is summarized below:

| | |
|---|---|
| Embankment | $26.5 million |
| Tunnels | $19.0 million |
| Emergency spillway | $ 1.5 million |
| Sub Total - Construction | $47.0 million |
| Clearing | $ 1.5 million |
| Sub Total | $48.5 million |
| Contingencies (20%) | $ 9.7 million |
| Engineering (15% of Construction) | $ 7.0 million |
| Grand Total | $65.2 million |

## Potential for a Multi-Purpose Project

Construction of a major dam and creation of a reservoir as considered in this study would provide the opportunity for considerable regulation of the flow in the Smoky River. However, given the prime objective of flood control it is difficult to conceive of substantial benefits for power generation or recreation. Modification of the conceptual design would be necessary at likely substantial cost to provide for compatible operation of the facilities.

Extensive studies of the market potential for power and comparison of alternative projects would be necessary prior to assigning any potential benefits to this particular proposal.

Although there are a number of small licenced withdrawals from the Smoky River downstream of the site these have been adequately supplied from the natural flow in the river and regulation would afford no additional benefits.

In summary, no major beneficiaries from the project apart from the Alberta Resources Railroad have been identified.

## Ecological Considerations

A broad assessment of some of the implications of creating a reservoir in this area was sought from the staff of the Fish and Wildlife Division of the Department of Lands and Forests. The comments were as follows:

1. The reservoir would flood the area known as the Kvass Flats as shown on Figure 1. The Kvass Flats support an overwintering population of elk and some moose from a wide summer range. A program or range improvements through bull dozing and burning poplar bluffs on the grass flats has been undertaken in the area for the past two years. If the reservoir is constructed, the cost of providing alternative elk ranges in the area should be an integral part of the design cost.
2. A dam would act as a barrier to the upstream migratory movement of Dolly Varden trout and Mountain whitefish, and could block access to critical spawning areas.
3. Rapid drawdown could result in additional heavy siltation in the Smoky River system downstream from the reservoir.
4. The reservoir would effectively isolate the land west of the Smoky River for a considerable time during high flows, reducing the recreational use of this area.
5. The reservoir would greatly diminish the scenic and aesthetic potentials of the Grande Cache area during drawdown conditions. This would affect both the town of Grande Cache and Willmore Wilderness Park.
6. The proposal operating regime would eliminate any fishery potential for the reservoir.

These comments would indicate that a flood control dam would have detrimental effects on both fish and wildlife in the area. Time was insufficient for any of these negative aspects to be quantified, and considerable study of these problems would be a prerequisite to further consideration of large storage works on the upper Smoky River. In addition the basic concept of locating the reservoir adjacent to or within the Willmore Wilderness Park should be considered in relation to policies and objectives associated with such areas.

## Conclusions

The following conclusions have been formed from this preliminary office study.

1. Flooding from a storm similar to that experienced in June 1972 could be controlled by providing a storage reservoir in the upper Smoky River basin.
2. There are a number of locations at which sufficient storage could be provided.
3. A preliminary estimate of gross costs for such a scheme is in the order of $65 million.
4. A dam in this area appears to offer little potential benefit beyond flood control.
5. Possible dis-benefits in terms of the ecology of the area have been identified.
6. Detailed investigations would be necessary to confirm the conceptual design adopted for costing purposes.

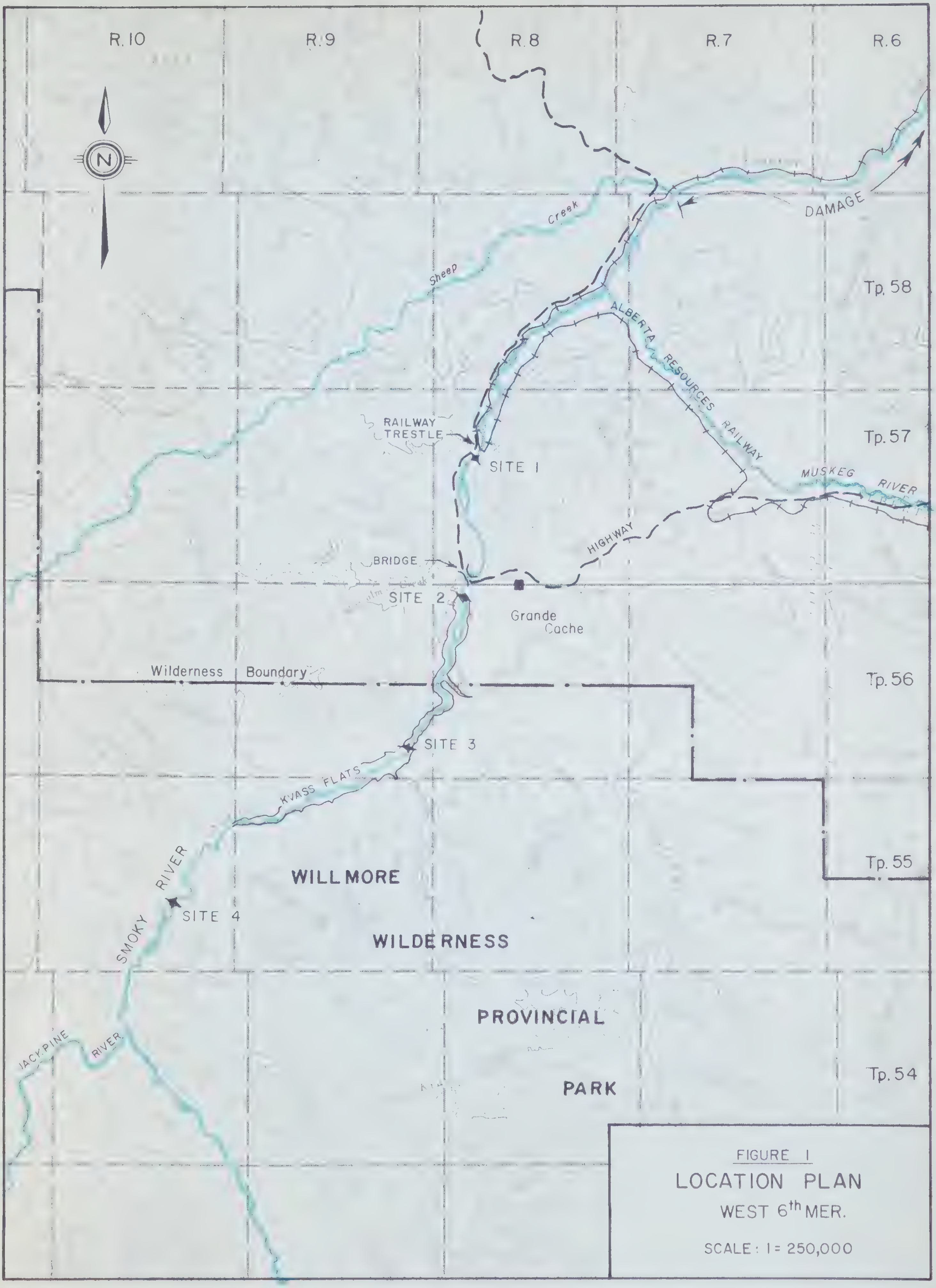
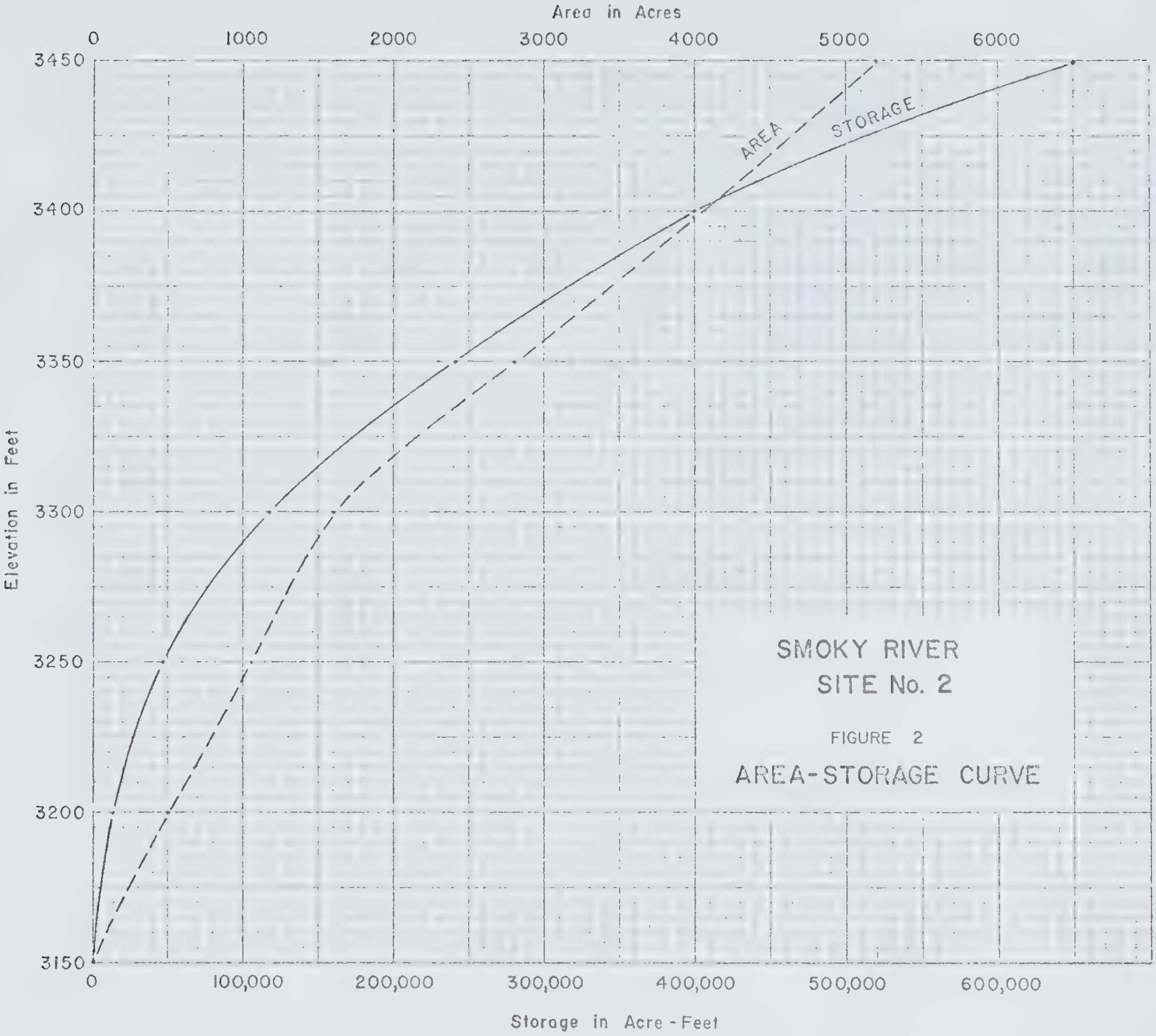


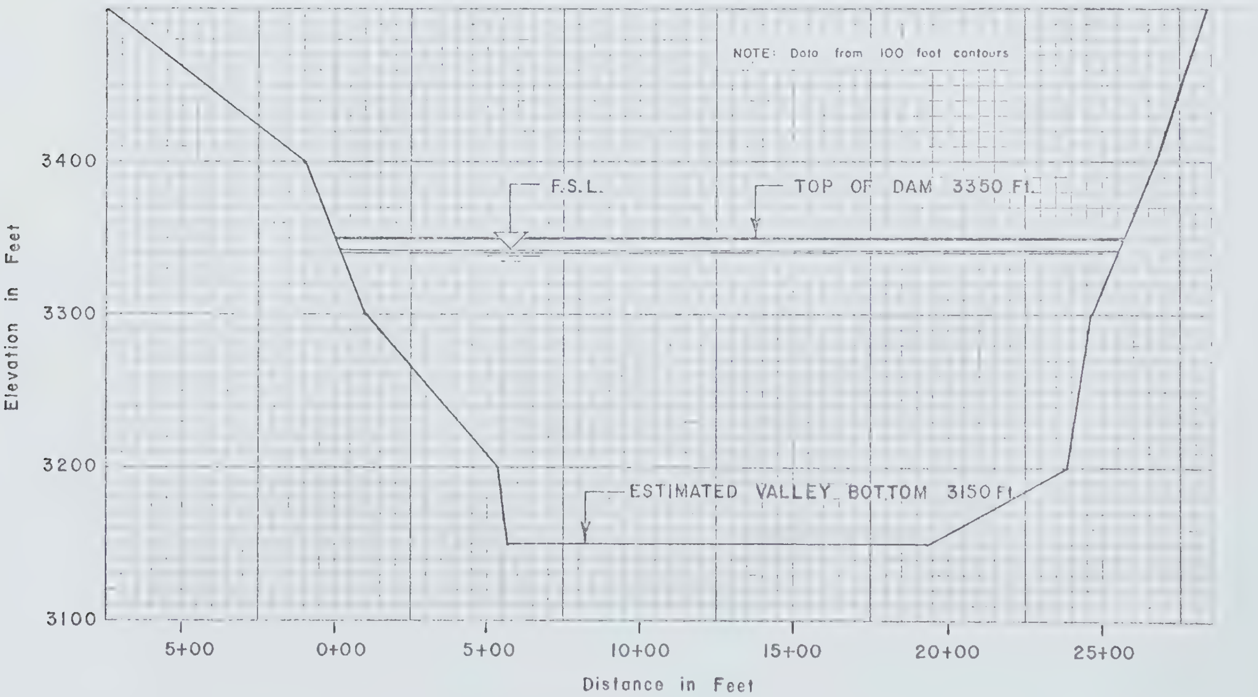
FIGURE 1
LOCATION PLAN
WEST 6th MER.
SCALE: 1 = 250,000



SMOKY RIVER
SITE No. 2

FIGURE 2

AREA-STORAGE CURVE



CROSS-SECTION

FIGURE 3

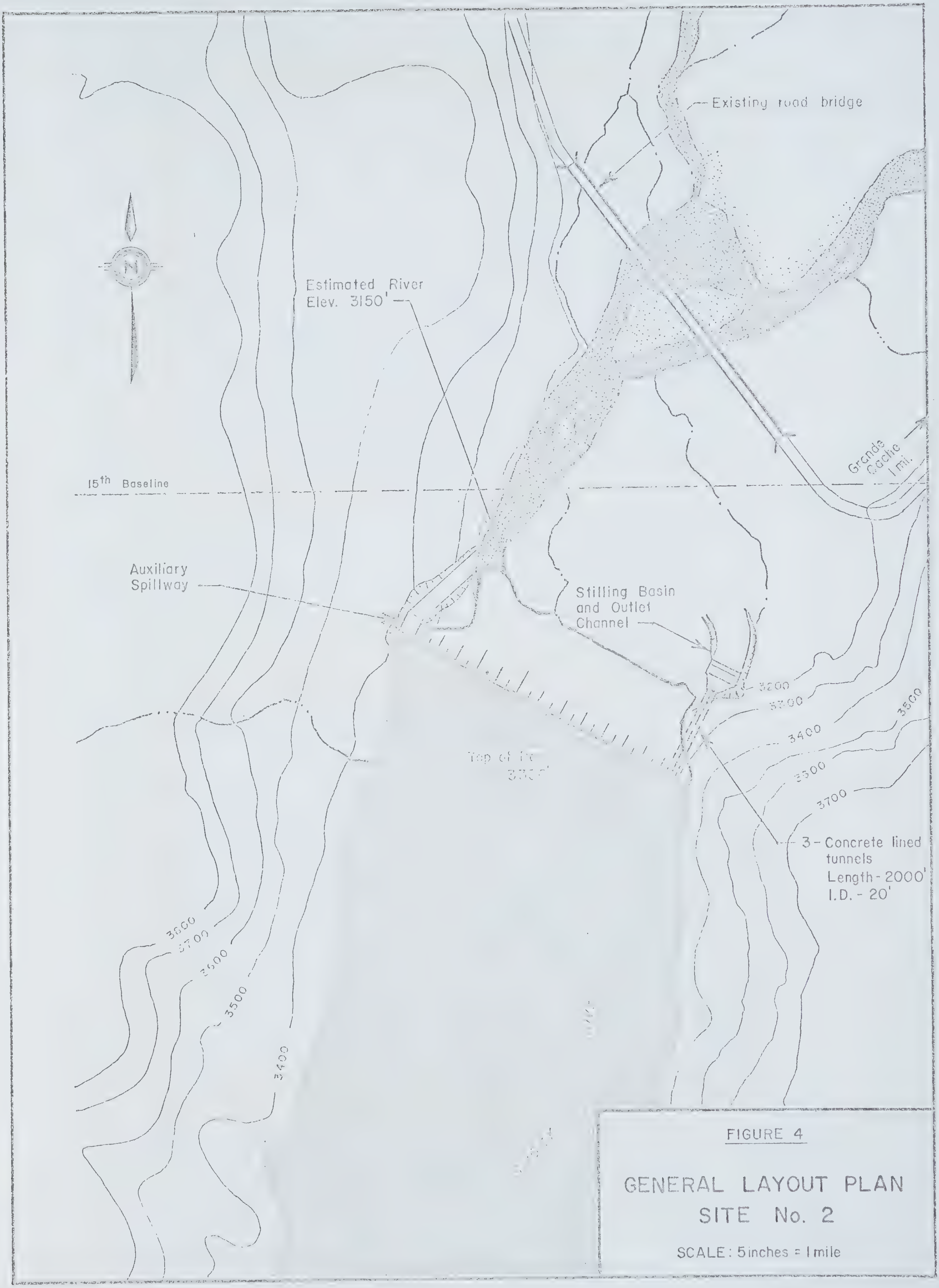


FIGURE 4

GENERAL LAYOUT PLAN
SITE No. 2

SCALE: 5 inches = 1 mile

FIGURE 5

INFLOW FLOOD HYDROGRAPH - JUNE, 1972
and
ASSUMED REGULATED OUTFLOW HYDROGRAPH

RESERVOIR OPERATION CRITERIA

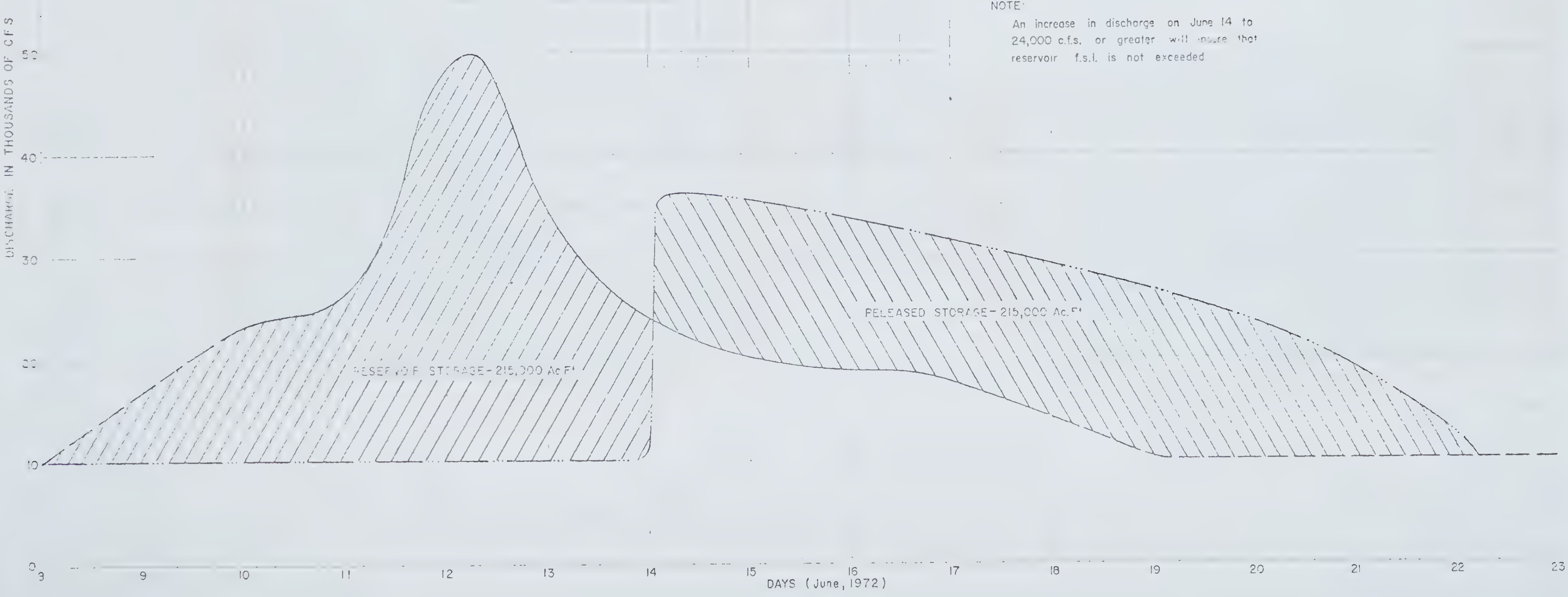
1. Release 10,000 c.f.s throughout storm.
2. Increase outflow about June 14.
   (maximum possible 36,000 c.f.s.)
3. Minimum time from peak to empty
   reservoir is 10 days (all 3 tunnels wide open)

LEGEND

——— Measured inflow
— — — Assumed inflow
—··· — Regulated outflow

NOTE:

An increase in discharge on June 14 to 24,000 c.f.s. or greater will insure that reservoir f.s.l. is not exceeded

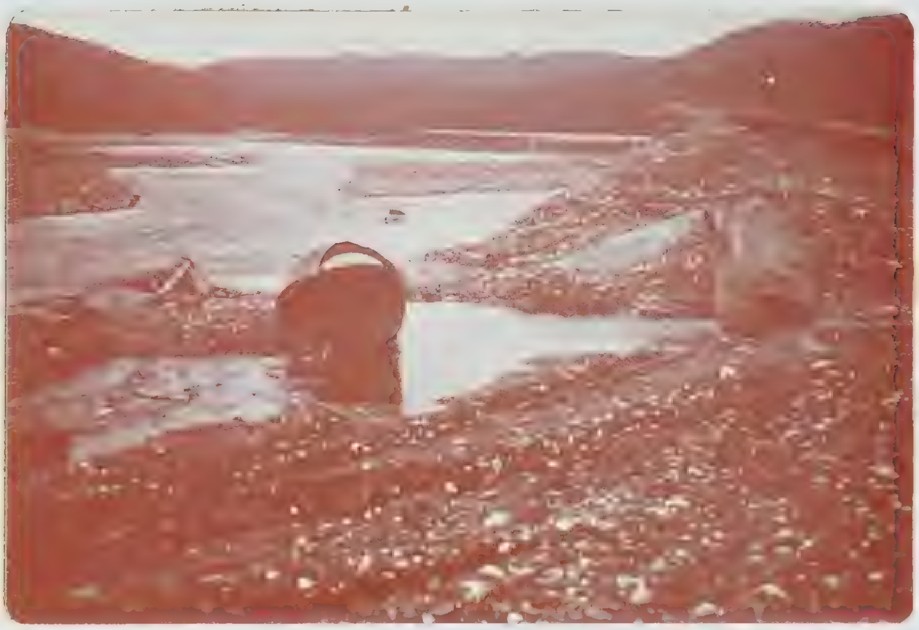


# APPENDIX F

## Photographic Coverage of the Alberta Resources Railway Along the Smoky River

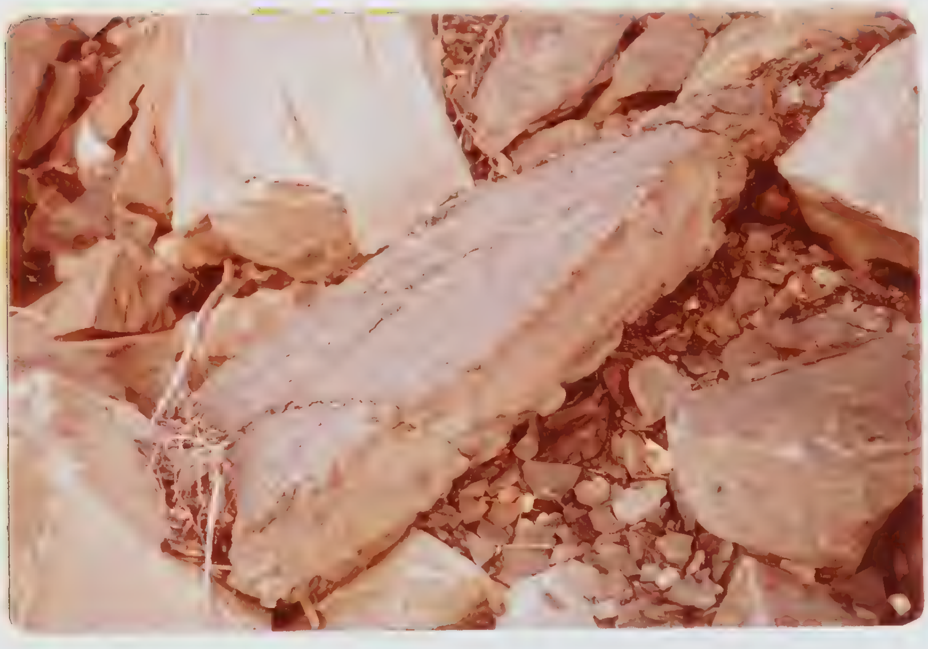
# APPENDIX F

## Photographs



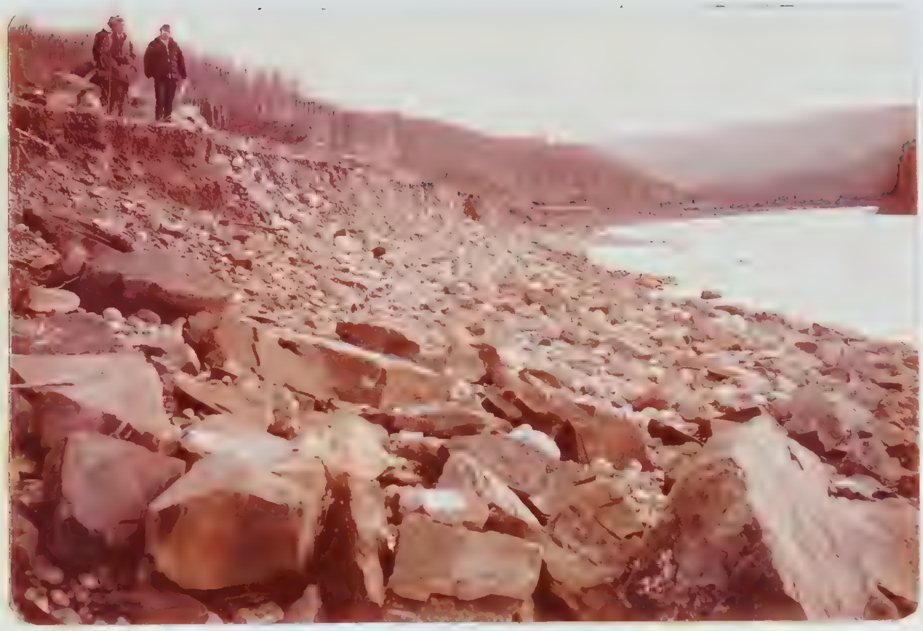
Photograph F.1

Mile 117 showing destroyed A.R.R. grade adjacent to the Smoky River. Note that the culvert is filled with gravel which was likely carried down from a small tributary basin, plugging off culvert and causing overtopping of embankment from behind.



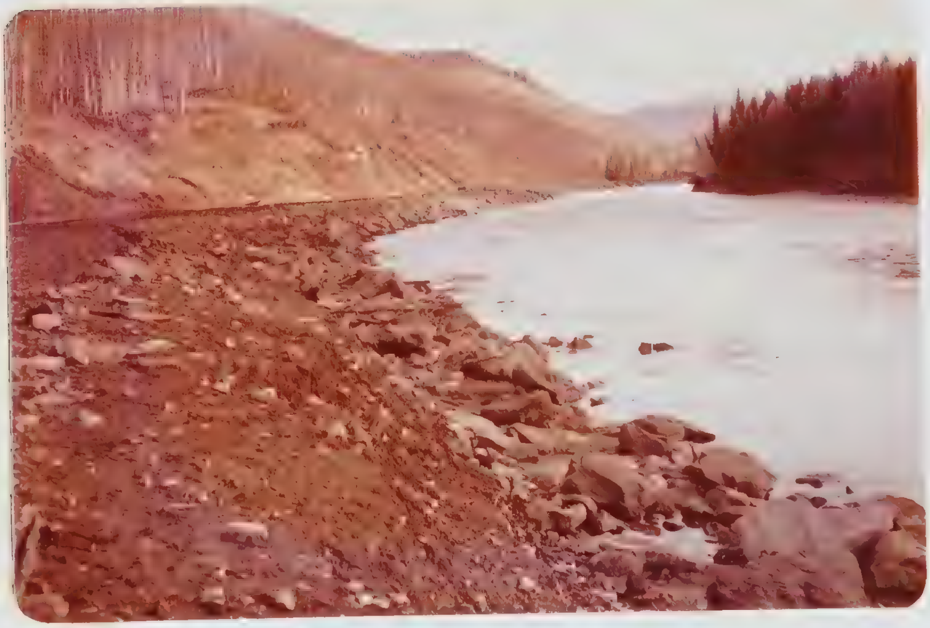
Photograph F.2

Mile 118 showing typical sandstone rip rap used. Maximum longitudinal measurement of stone about five feet but stones are flat. Thickness about twelve inches. Note lack of intermediate sizes between small underlying material and larger stone on surface. Sandstone was noticeably weathering.



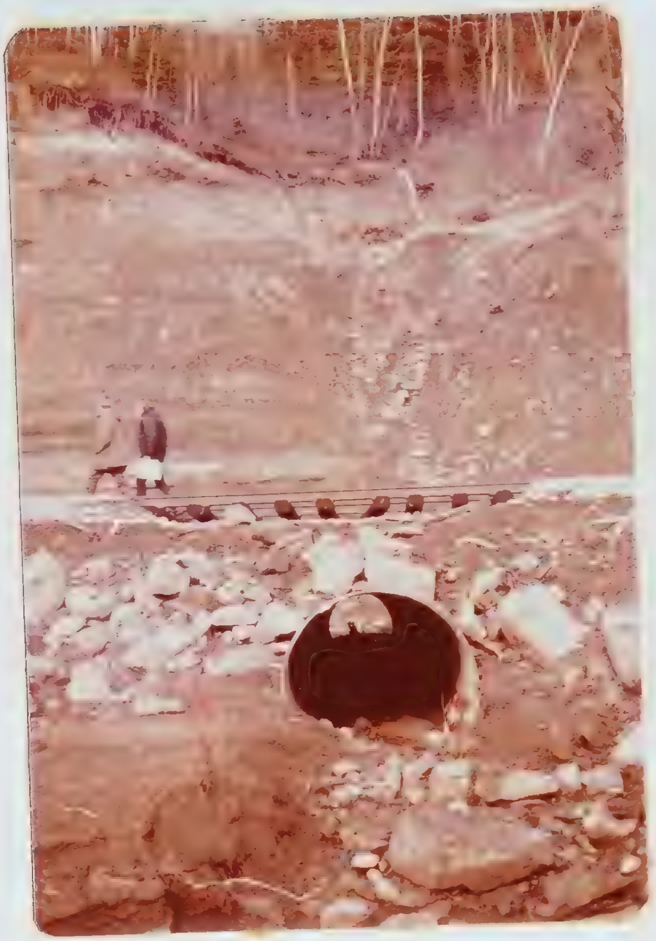
Photograph F.3

Mile 118 looking downstream showing start of section of embankment removed during flood. Foreground shows sandstone rock used for rip rap while below this the toe of the embankment is cobbled with large gravel and sandstone remnants.



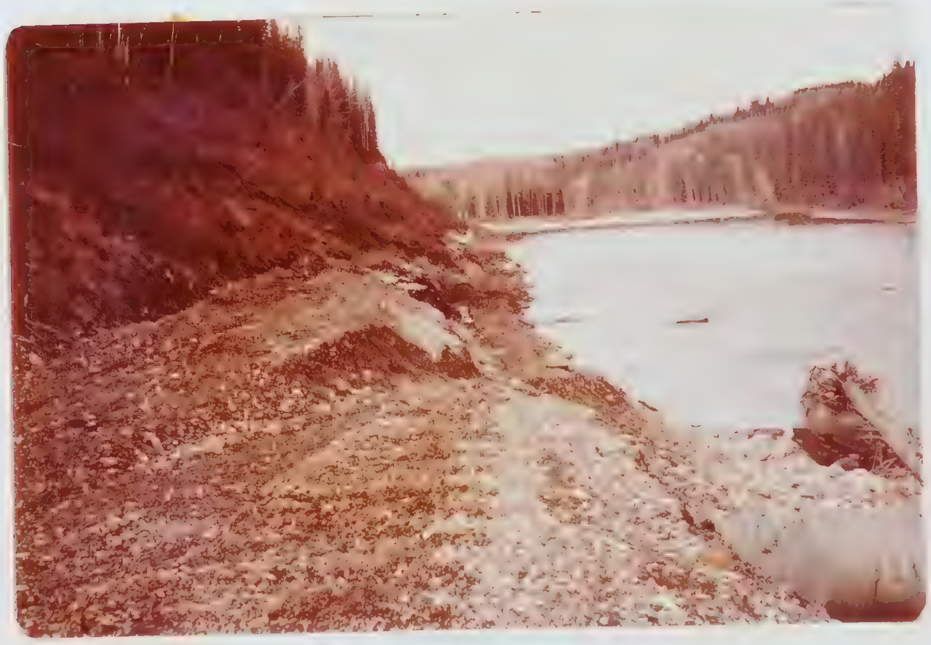
Photograph F.4

Mile 119 looking downstream at constricted Smoky River channel. Note rip rap material along toe of embankment.



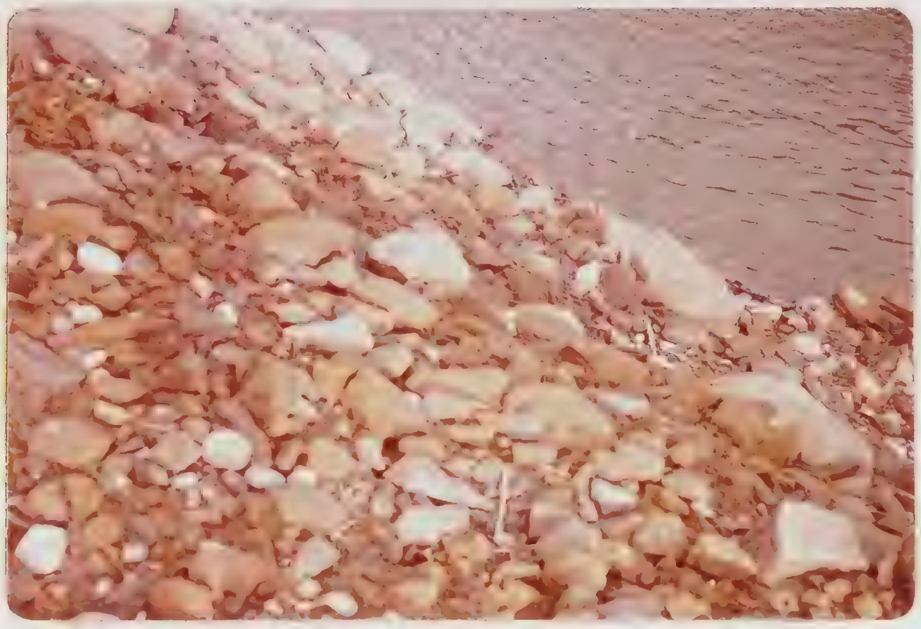
Photograph F.5

Mile 136 showing result of culvert not being able to handle flow and overtopping grade. Ballast has been scoured out.



Photograph F.6

Mile 144.5 looking downstream indicating how original A.R.R. embankment extended into river channel. Embankment has been completely removed by flood.

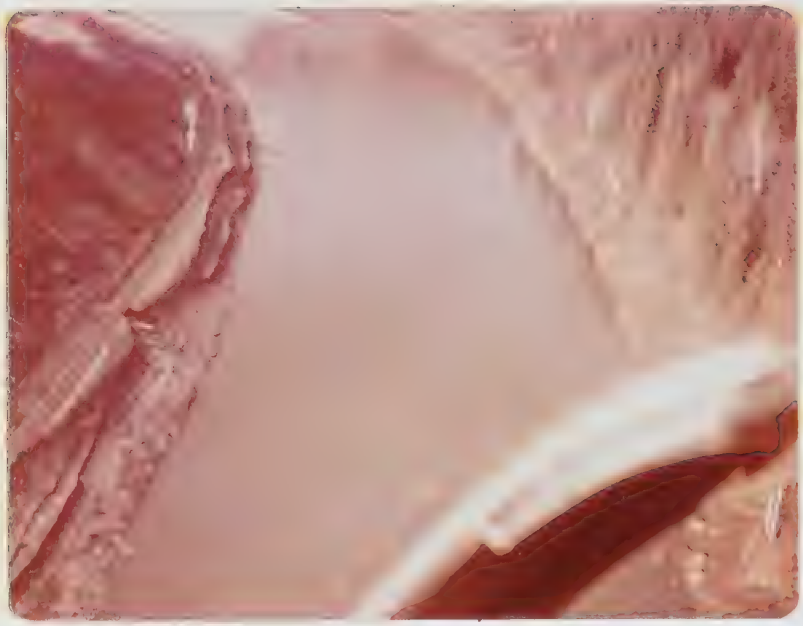


Photograph F.7

Mile 145 showing sandstone rip rap. The light brown rocks would disintegrate when kicked.

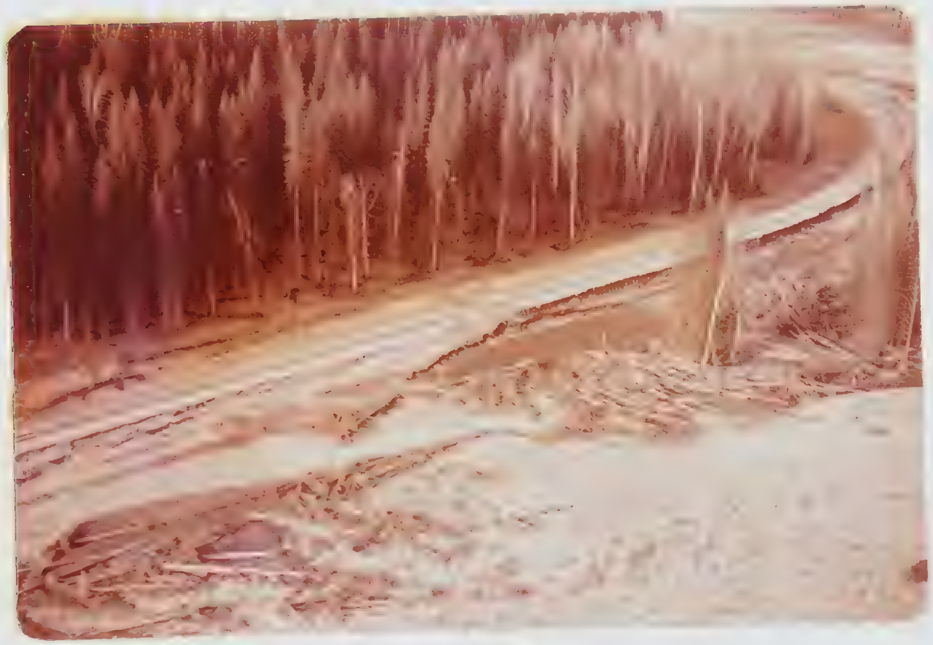
Photograph F.8

Typical tight turn in river where damage has occurred at point of severest attack.



Photograph F.9

Channel constricted by A.R.R. embankment. Note how damage has occurred on inside of bend.



Photograph F.10

Damage has occurred where flow cut across inside of bend, through treed area along embankment right-of-way.